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Evaluation of innovative volatile organic compound and hazardous air pollutant control technologies for U. S. Air Force paint spray booths

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EVALUATION OF INNOVATIVE VOLATILE ORGANIC COMPOUND AND HAZARDOUS AIR POLLUTANT CONTROL TECHNOLOGIES FOR U.S. AIR FORCE PAINT SPRAY BOOTHS

PILOT-SCALE TEST RESULTS

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ABSTRACT

EVALUATION OF INNOVATIVE VOLATILE ORGANIC COMPOUND AND HAZARDOUS AIR POLLUTANT CONTROL TECHNOLOGIES FOR U. S. AIR FORCE PAINT SPRAY BOOTHS

PILOT-SCALE TEST RESULTS

by Dean Harrison Ritts

In this report, carbon paper adsorption/catalytic incineration (CPACI) and fluidized-bed catalytic incineration (FBCI) were evaluated as control technologies to reduce volatile organic compound (VOC) emissions from paint spray booths. Simultaneous testing of pilot-scale units was done to evaluate the technical performance of both technologies. Results showed that each technology maintained greater than 99 percent Destruction and Removal Efficiencies (DREs). Particulate emissions from both pilot-scale units were less than .08 grains/dry standard cubic feet. Emissions of the criteria pollutants, SO_x, NO_x, and CO were also below general regulatory standards for incinerators. Economic evaluation was based on a compilation of manufacturer supplied data and energy consumption data gathered during the pilot-scale testing. CPACI technology is more expensive to purchase and install, $1,425,000 for a 50,000 dscfm unit, than FBCI technology, $1,062,500. Annual energy costs for CPACI technology are lower than

the costs for FBCI technology. The CPACI technology has a projected energy cost of $60,250 per year. FBCI technology annual energy cost is expected to be $91,700.

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LIST OF ABBREVIATIONS

APCD	Air Pollution Control District
AFESC	Air Force Engineering Services Center
BAAQMD	Bay Area Air Quality Management District
BAAQMD ST7	Bay Area Air Quality Management District sampling and analysis procedure for continuously monitoring the total unburned hydrocarbon concentration in a gas stream
CAA	Clean Air Act
CPACI	Carbon Paper Adsorption/Catalytic Incinerator
DQO	Data Quality Objective
DRE	Destruction and Removal Efficiency
EPA	United States Environmental Protection Agency
EPA M2	Environmental Protection Agency Method 2 flowrate measuring procedure
EPA M5	Environmental Protection Agency Method 5 sampling and analysis procedure for determining particulate concentrations in ducts isokinetically
EPA M25A	Environmental Protection Agency Method 25A sampling and analysis procedure for continuously monitoring the total unburned hydrocarbon concentration in a gas stream
FBCI	Fluidized-Bed Catalytic Incinerator
GC/MS	Gas Chromatograph/Mass Spectrometer
HAP	Hazardous Air Pollutant
NDIR	Non Dispersive Infrared

NIOSH	National Institute of Occupational Safety and Health
NIOSH 1300	Air sampling method for determining organic compound concentrations in air
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RPD	Relative Percent Difference
TUHC	Total Unburned Hydrocarbon
VOC	Volatile Organic Compound

CHAPTER I

INTRODUCTION

This document presents the results of pilot-scale testing conducted for the United States Environmental Protection Agency (EPA) under Work Assignment Number 1/025 of EPA Contract Number 68-02-4285. The United States Air Force and the Environmental Protection Agency are concerned about VOC emissions from aircraft maintenance facilities. Acurex investigated innovative technologies for control of VOC emissions from Air Force paint spray booths. Acurex selected two specific technologies and installed, operated, tested, and evaluated each VOC control system. The technologies that were evaluated on the pilot-scale level were fluidized-bed catalytic incineration (FBCI) and carbon paper adsorption/catalytic incineration (CPACI).

The pilot-scale testing and evaluation of the selected innovative technologies represents a joint effort between the U.S. Air Force Engineering Services Center (AFESC) and the EPA Air and Energy Engineering Research Laboratory (AEERL) under a letter of agreement between the EPA and the Department of Defense (DOD).

A. Background

The Air Force (AF) uses a number of organic solvents and coatings for aircraft and aircraft-related equipment maintenance.[1] This maintenance includes such operations as metal cleaning, painting, paint removal, fuel storage and transfer, and industrial waste treatment processes. These operations release large quantities of volatile organic compounds (VOC) and hazardous air pollutants (HAP) into the atmosphere. Consequently, the USAF has been identified as a VOC and HAP emissions source and is regulated by the Clean Air Act (CAA) and related state and local regulations.[1] Because many USAF bases are located in regions that have not yet attained pollution control goals set by the CAA, local Air Pollution Control Districts (APCDs) are applying increased pressure on the AF to decrease its VOC and HAP emissions.

In response to these regulations, the AFESC has initiated technology evaluation programs to minimize VOC and HAP emissions through source control reductions and system modifications to existing paint spray booth operations.[1] This work assignment focuses on the emissions from paint spray booths where solvent-based epoxy primers and polyurethane topcoats are normally used. The primary VOCs are methyl ethyl ketone (MEK),

isopropyl alcohol, toluene, lacquer thinner, and aliphatic polyurethane thinner.[2]

B. Literature Review

Previous research concerning the control of VOCs and HAPs from paint spray booths is limited to a few government sponsored projects. Manufacturer supplied data concerning the performance of specific VOC control devices is available but should be viewed with some skepticism. Research conducted by the manufacturer may not always be reliable since some element of bias may intrude into the results.

Early work in the field dates back to 1978 when Radian Corporation published a report entitled, "Control Techniques for Volatile Organics Emissions from Stationary Sources."[2] This report was prepared for the US EPA Office of Air Planning and Standards and summarized VOC emission control technologies in general. Basic information concerning the destruction and removal efficiencies (DREs), economics, and applicability of various control technologies was provided. Some discussion was given to the abilities of incineration and catalytic incineration technologies to control VOC emissions from solvent coating operations.

Research which investigated the nature of emissions from Air Force paint spray booths was carried out in 1987 by Acurex Corporation under the direction of the US EPA. "Volatile Organic Compound and Particulate Emission Studies of DOD Paint Booth Facilities: Phase 1," was published in January, 1988.[3] This report was based on field testing of three operating paint spray booths (located at McClellan AFB and Travis AFB, Ca.) and documented VOC and HAP emissions from them. When results from the research are converted to daily emission rates, it is evident why the EPA and air pollution control agencies are concerned. Average paint spray booth VOC emission rates were 64 kg/day while maximum daily emissions reached 145 kg/day. This is in excess of many of the air pollution standards set by California air pollution control districts. The Bay Area Air Quality Management District limits daily VOC emissions from paint spray booths to 18 kg/day.[4] Thus, uncontrolled VOC emissions from Air Force paint spray booths can exceed regulatory standards by 3.5 fold and often by 8 fold.

Because of the data generated in the previously mentioned report, an investigative study of innovative VOC control technologies was sponsored by the EPA. This manufacturer survey was conducted by Acurex and published as, "Evaluation of Innovative Volatile Organic Compounds

(VOCs) and Hazardous Air Pollutants (HAPs) Emissions Control Concepts and Systems for USAF Paint Spray Booths".[5] This report identified numerous technologies and evaluated 11 of the most promising VOC emission control sytems. The main objective of this report was to select three innovative technologies to be field tested at an Air Force base. The technologies chosen for pilot-scale testing were fluidized-bed catalytic incineration, carbon paper adsorption/catalytic incineration, and regenerative thermal oxidation.

These technologies were chosen since they incorporated VOC control strategies based on the destruction of the pollutants. Other control methods, such as vapor-phase carbon adsorption, only effect a cross-media transfer of the VOCs. The contaminants are pulled from the influent air and adsorbed on to the carbon bed. This results in the carbon bed being contaminated and it must be disposed of properly. Incineration technologies represent ultimate solutions to the pollution problem because they destroy the VOCs. This reasoning is what led Acurex to recommend that innovative incineration technologies be evaluated at the pilot scale.

C. Purpose of Pilot-Scale Testing

The purpose of the pilot-scale testing was to evaluate the economic and technological performances of selected VOC control technologies as applied to job shop type paint spray booths. The primary technologies to be evaluated were to be innovative technologies that were not currently in use on paint spray booths, or had only recently been applied to booths. A further constraint was that they must be at least at the pilot stage of testing. The purpose of the work reported on in this document was to provide the basic information from which to scale the technology performance to full-scale operation.

D. Approach

The approach for the acquisition of performance data was to gather operational data in the field. The technologies were to be evaluated by studying the performance of selected units with respect to emissions from an actual spray paint booth. Field testing of two pilot-scale VOC emission control technologies was done at McClellan AFB. Air emissions from a paint spray booth at Building 665 were split and vented to the treatment units for side-by-side technology evaluation. The two innovative technologies evaluated were carbon paper

adsorbtion/catalytic incineration and fluidized-bed catalytic incineration.

E. Report Organization

Chapter I is the introduction to this report. Chapter II provides descriptions of the testing facilities and the pilot-scale units. Chapter III details the testing program utilized to evaluate the VOC emission control technologies. Results and discussions supporting the conclusions and recommendations are presented in Chapter IV. Quality Assurance and Quality Control information is presented in Chapter V. Chapter VI provides the conclusions and recommendations of this study. Appendix A explains the technical approach for data reduction and contains sample calculations. Spreadsheets for DRE data reduction are presented in Appendix B. As-built diagrams for the project are shown in Appendix C.

CHAPTER II

FACILITY DESCRIPTION

A. Test Site Description

A paint spray booth (Big Bertha booth) in Building 655 at McClellan Air Force Base was the test site for the pilot-scale tests. The paint spray booth is a dry wash paint spray booth. The unit is approximately 50 ft long by 22 ft wide by 15 ft high. It has dry filters in the front and some filters in the back. The dry filters in the front are used to filter overspray droplets and particulates. The filters at the back remove large-size (>10μm in diameter) paint overspray particles from the booth exhaust and also reduce the concentration of small-size (<10μm) paint overspray particles to a minimum. Air enters the front of the booth and exits at the back at an air velocity of 100 feet per minute. Air is drawn through the booth with two fans which draw a total of 32,000 ft^3 per minute (CFM). The facility is normally used to paint large semi-trailer-size equipment and other moderate-size equipment such as communication shelters.

Site preparation required design and installation of ductwork to split a fraction of the total booth output to

the pilot test pad. This effort included specification, acquisition, and installation of accessory equipment, electrical design and installation, and preparation of system layout drawings. The "as builts" for the ductwork are shown in Appendix C. As described previously, the 32,000 CFM of vapor from the paint spray booth is exhausted through two 43-inch ducts. About 4000 CFM of the vapor from one of the exhausts was drawn through a 20-inch-diameter galvanized iron duct. Duct work was designed to allow simultaneous testing of the two systems. The total length of the duct work from the paint spray booth exhaust to the nearest test unit (Fluidized-Bed Catalytic Incinerator) was about 61 feet.

Both of the test units were skid-mounted and set on 2-inch-thick asphalt. A 1000-gal propane tank that supplied propane gas to the FBCI was mounted on a saddle about 25 feet away from the unit. The test systems were secured within a 34-ft by 50-ft fence. The FBCI used propane gas because the nearest natural gas line at McClellan Air Force Base is at the opposite side of Building 655. Both pilot-scale units required electrical power.

B. Description of Innovative Technologies Which Were Field Tested

1. Fluidized-Bed Catalytic Incineration

Fluidized-bed catalytic incineration (FBCI) was evaluated as a VOC control technology by field testing a pilot-scale unit supplied by ARI Technologies, Inc. The pilot-scale unit consisted of three main components: a catalyst bed, a burner with combustion chamber, and a forced draft fan. The pilot-scale FBCI was sized for 500 scfm and could operate at flowrates as low as 250 scfm. Operating temperatures can range from 550 to 1250°F, but are generally maintained between 550 to 700°F.

VOC-laden air is preheated by direct contact with a natural gas burner. This provides 20 to 50 percent of the total destruction of VOCs. The heated gas then flows through a baffled distribution grate and into a bed of fluidized catalyst spheres. The catalyst spheres consist of a proprietary metal oxide coated on aluminum oxide pellets. The exhaust from the catalyst bed is vented to the atmosphere. Full-scale units incorporate a heat exchanger into the design prior to the exhaust gas being vented. Figure 1 is a schematic of the pilot-scale unit.

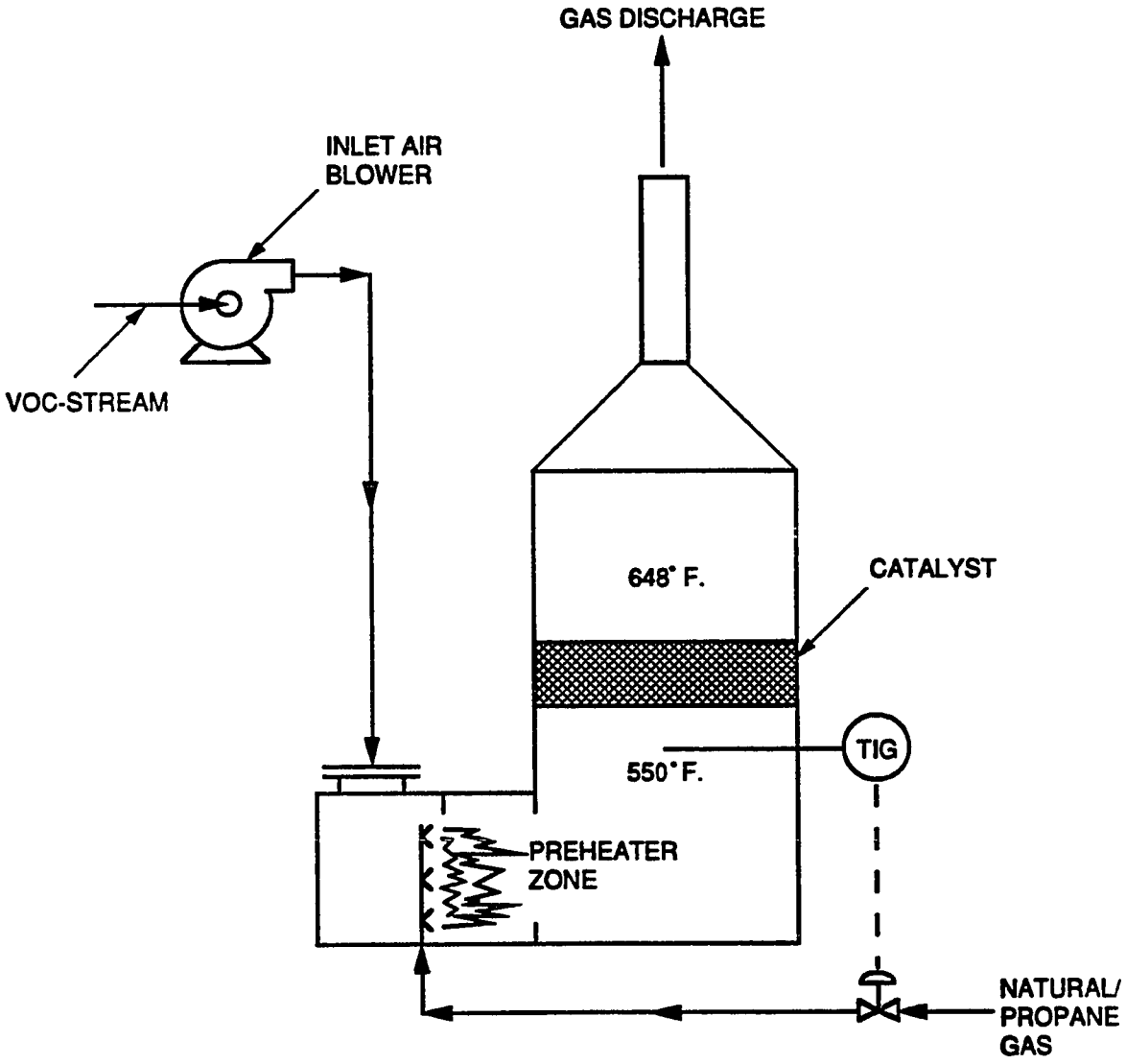


Figure 1. Process Flow Diagram for Fluidized-Bed Catalytic Incineration. (Adapted from Diagram Supplied by ARI International Catalytic Oxidation System.)

2. Carbon Paper Adsorption/Catalytic Incineration

Carbon paper adsorption/catalytic incineration (CPACI) was evaluated as a VOC control technology by field testing a pilot-scale unit supplied by Met-Pro Coporation. CPACI is a technology which combines carbon adsorption and catalytic incineration. Essentially, the contaminated air stream is cleaned by carbon adsorption. Catalytic incineration is used to destroy the VOCs that are desorbed from the carbon adsorption system. Figure 2 is a schematic of the pilot-scale unit. The purpose of the combined technologies is to reduce the volume of contaminated air that must be incinerated.

Air emissions from the paint spray booth are passed through a particulate filter and then a granular activated carbon filter. Next, the air flows through an innovative carbon paper filter which is fashioned into a cylindrically shaped, continuously turning rotor. The honeycombed structure of this carbon paper filter allows for a high removal efficiency of VOCs. Paint spray booth emissions pass through one end of the cylinder. However, air only passes through about 7/8ths of the area at the end of the carbon paper rotor (Figure 3). The filtered air is then exhausted to the atmosphere. The remaining 1/8th of filter area is used in the incineration loop of the CPACI technology.

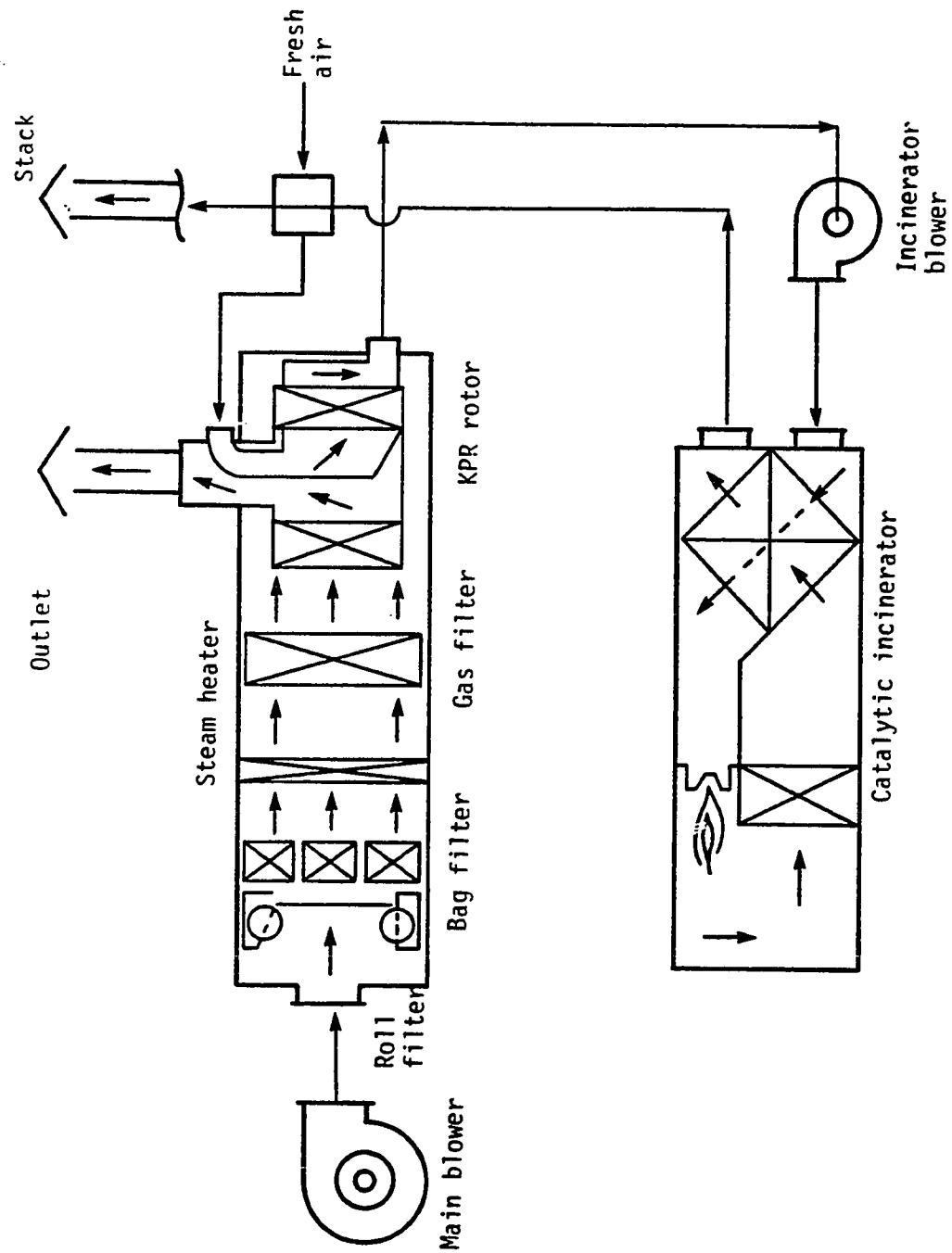


Figure 2. Process Flow Diagram for Carbon Paper Adsorption/Catalytic Incineration (Met-Pro Corporation KPR Process). (Adapted from Diagram Supplied by Met-Pro Corporation.)

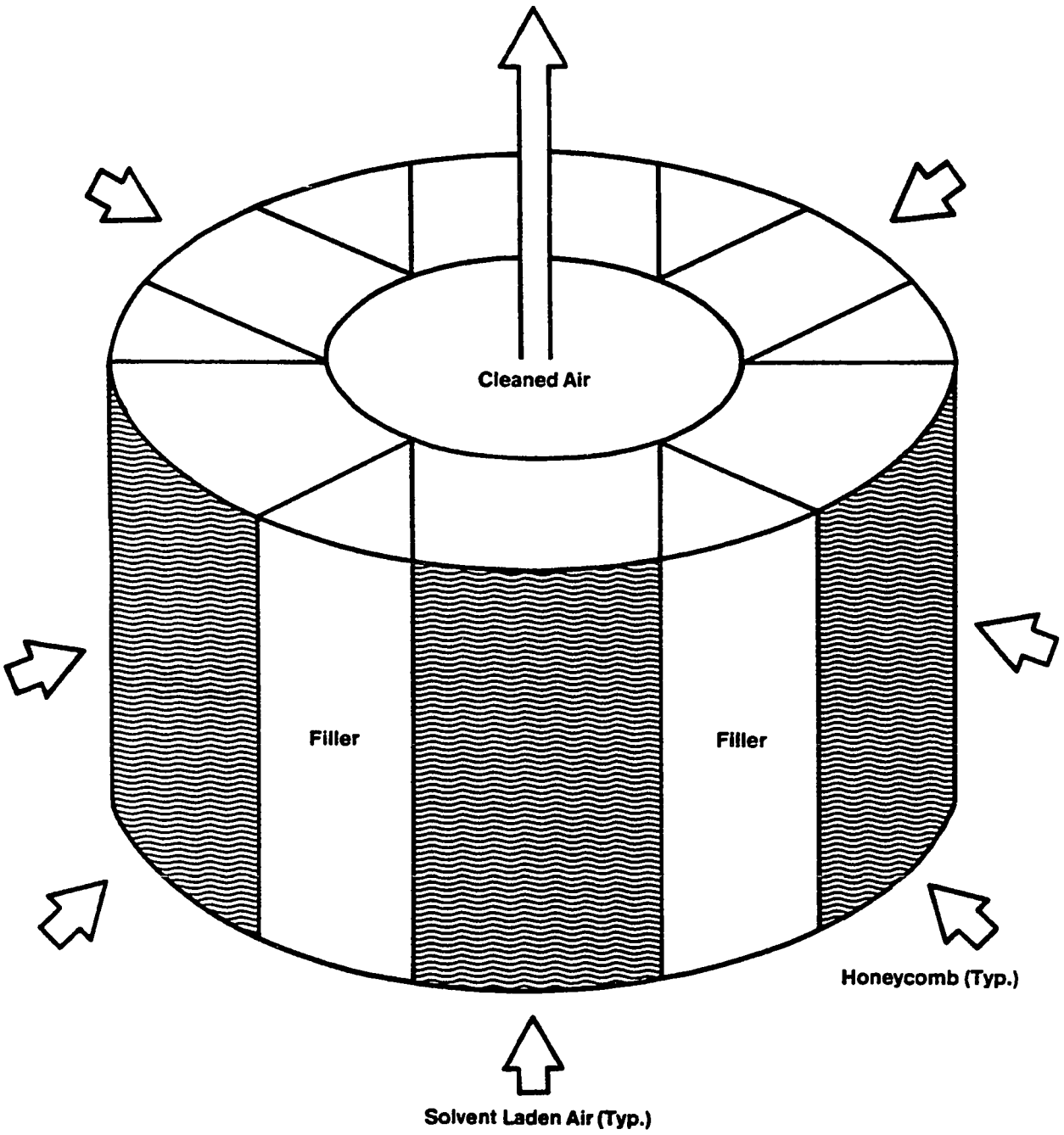


Figure 3. KPR Cylinder Type Rotor Adsorbing.

Since the carbon paper filter is always rotating, there is always a portion of the filter adsorbing VOCs from the contaminated air. There is also a part of the carbon paper rotor always moving into a counter-current stream of hot desorption air (Figure 4). This air represents a separate stream entering the CPACI at a flowrate about 1/15th that of the air emissions coming from the paint spray booth. This desorption air stream is preheated by a heat exchanger, then it desorbs the VOCs from the carbon paper rotor and carries them to a catalytic incinerator. The VOCs are destroyed by the catalytic incinerator and the desorption air is then exhausted to the atmosphere. The pilot-scale CPACI consists mainly of a carbon paper adsorber, ceramic catalyst bed, heat exchanger and electrical heaters.

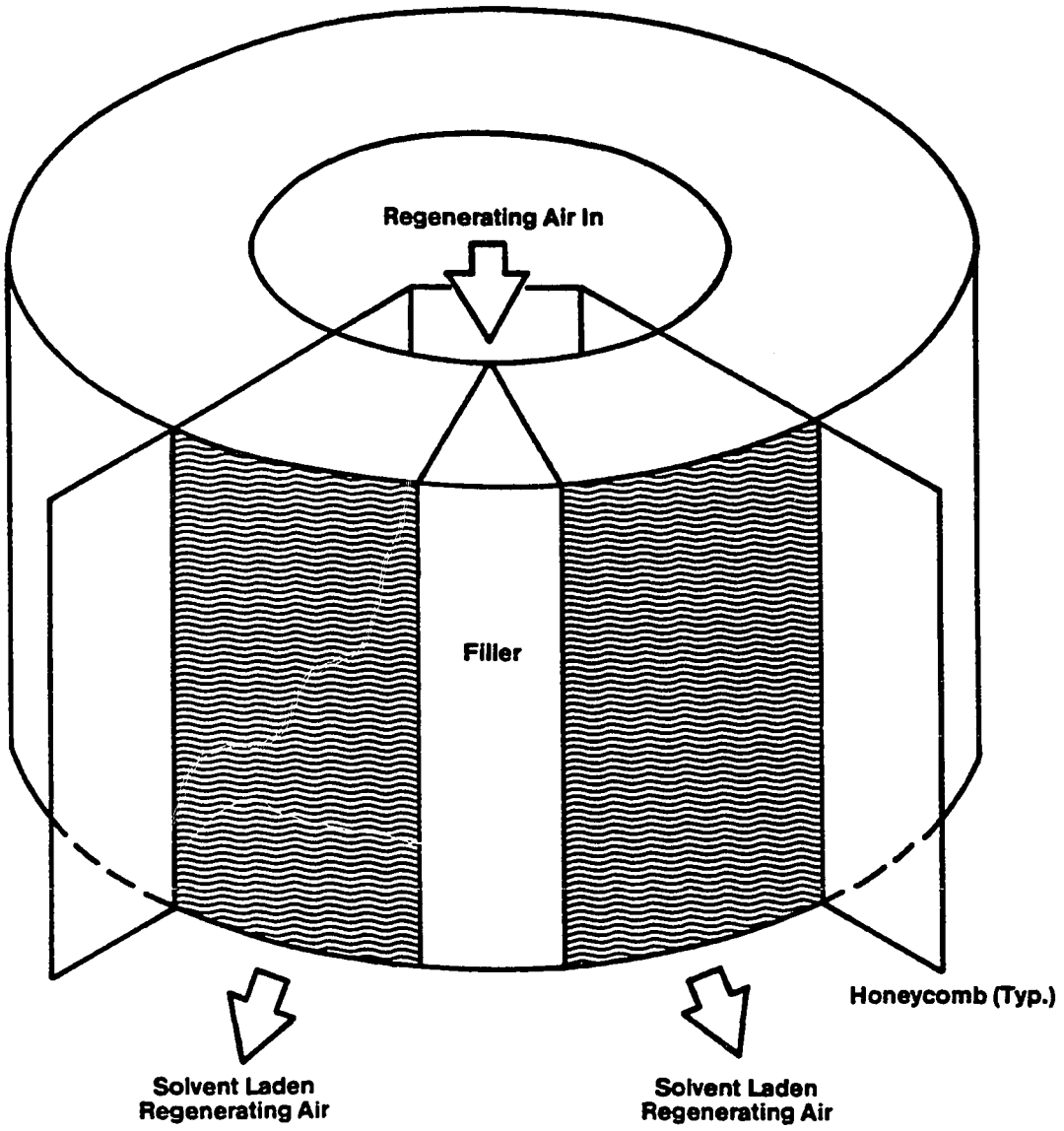


Figure 4. KPR Cylinder Type Rotor Desorbing.

CHAPTER III

TEST PROGRAM DESCRIPTION

This chapter discusses the test program, including the test matrix, pilot-scale system operation, the painting schedule, tests methods, and field comments.

A. Test Matrix

The fundamental technical approach used for evaluating the two control technologies was to determine their efficiencies in controlling VOC emissions. This was accomplished by measuring inlet and outlet VOC concentrations and the energy consumption of each unit. The critical parameters measured were the hydrocarbon DRE and the energy required to operate the units. Measurements of hydrocarbon concentration and air flow were used to calculate DRE values. Measurements of gas and electrical usage were used to estimate energy consumption.

There were eight sampling sites, as described below. Exhaust from the paint spray booth was sampled at Sites 1 and 1A, prior to reaching the control devices. Sampling location 2 is where electrical power input data for the

CPACI and the FBCI unit were taken. Propane gas input data for the FBCI unit was taken at location 3. The FBCI exhaust sampling was performed at location 4. The CPACI had two exhaust sites that were sampled. Site 5 was the carbon paper exhaust and Site 6 was the incinerator exhaust. Flowrates for the inlet streams to the control devices were tested at Sites 7 and 8 for the CPACI unit and the FBCI unit, respectively.

Paint spray booth emissions were sampled and analyzed for four parameters. These parameters were particulate matter concentration, organic speciation, total unburned hydrocarbon (TUHC), and volume flowrate. EPA Method 5[6] and EPA Method 2[7] were used to measure particulate matter concentration and volume flowrate, respectively. These sampling methods were performed at sampling site 1A. Organic speciation and TUHC concentration of the paint spray booth exhaust were measured at Site 1. TUHC measurements were made by using BAAQMD Method ST-7.[8] Organic speciation of the paint spray booth exhaust was determined by NIOSH 1300 method.[9] Concentrations of CO_2, CO, O_2, and NO_x, in the paint spray booth exhaust, were assumed to be the same as ambient air levels. The design of the paint spray booth should not alter the concentrations of these parameters.

CPACI exhaust measurements were made of particulate matter concentration, organic speciation, TUHC, volume flowrate, CO, CO_2, O_2, and NO_x. These measurements were made at the CPACI exhaust points, Site 5 and Site 6. Site 5, the carbon paper exhaust, was checked for CO, CO_2, O_2, and NO_x emission levels to verify that these parameters were at ambient levels. These parameters were recorded on a regular basis for Site 6, the CPACI incinerator exhaust. EPA Methods 3A, 7E, and 10[10,11,12] were used for monitoring CO_2, O_2, NO_x, and CO. TUHC concentrations at both Sites 5 and 6 were measured according to EPA Method 25A specifications.[13] Particulate matter concentration at Site 6 was measured by using an EPA Method 5 sampling train. The CPACI carbon paper was not expected to have any particulate matter since the air is filtered three times before it is exhausted. Therefore, particulate sampling was not done at this location. Organic speciation of CPACI exhaust gases on volume flowrates were performed at both Sites 5 and 6. The test methods used were the NIOSH 1300 method and EPA Method 2. FBCI exhaust was evaluated for the same parameters as was the CPACI exhaust, and the same sampling methods were used.

A summary of the tests performed, the data collected, and the quantities of samples taken during the

entire sampling effort are presented in Table 1. This table lists the site numbers and locations, the type of sample taken, and the total number of sampling events. The methods used to monitor each of these parameters are summarized in Table 2. Figure 5 shows the configuration of the sampling sites.

The VOC control devices were tested under numerous operating conditions. One objective of the test program was to evaluate the technologies during operating conditions that would promote worst-case destruction efficiency, optimum destruction efficiency/operational costs and worst-case operational costs. The low temperature/high flowrate condition was used to demonstrate the worst-case destruction efficiency. The optimum temperature/optimum flow condition was tested as the most efficient operating condition. The high temperature/high flow condition demonstrated the worst-case operational cost.

The temperatures and flowrates for the three operating conditions were finalized onsite with input from the vendors, EPA Project Officer, Air Force Project Officer, and the Field Test Crew Chief. Under the direction of these individuals, tests were also run at other operating conditions such as low temperature/high flowrate. The operating parameters for each condition

TABLE 1. SAMPLING MATRIX FOR CONTROL TECHNOLOGIES.

Site No.	Site Location	Number of Sampling Events					
		Volume Flow	Organic Speciation	Total Unburned Hydrocarbons	Particulate and Moisture	Moisture	Electricity Consumption
1	VOC emissions (organic sampling)	--	23	Continuous	--	--	--
1A	VOC emissions (particulate sampling)	14	--	--	12	--	
2	Electrical power input	--	--	--	--	--	Continuous
3	Propane gas input	--	--	--	--	--	Continuous
4	FBCI[a] incinerator exhaust	3	20	Continuous	18	1	--
5	CPACI main exhaust	20	22	Continuous	--	4	--
6	CPACI incinerator exhaust	14	22	Continuous	12	5	--
7	CPACI inlet[b]	46	--	--	--	--	--
8	FBCI inlet[b]	40	--	--	--	--	--

[a]Volume flow data are generated during the particulate and moisture test (EPA Method 5).
[b]Organic speciation data and total unburned hydrocarbon data for Site 1 is the same for Sites 7 and 8.
--Not applicable.

TABLE 2. SAMPLING METHODS.

Parameter	Method
Volume flow	EPA Method 2
Organic Speciation	NIOSH Method 1300
Inlet total unburned hydrocarbons	BAAQMD ST-7
Incinerator exhaust total unburned hydrocarbons	EPA Method 25A
Particulate and moisture	EPA Method 5
Moisture	EPA Method 4
Electricity consumption	Standard electrical meter

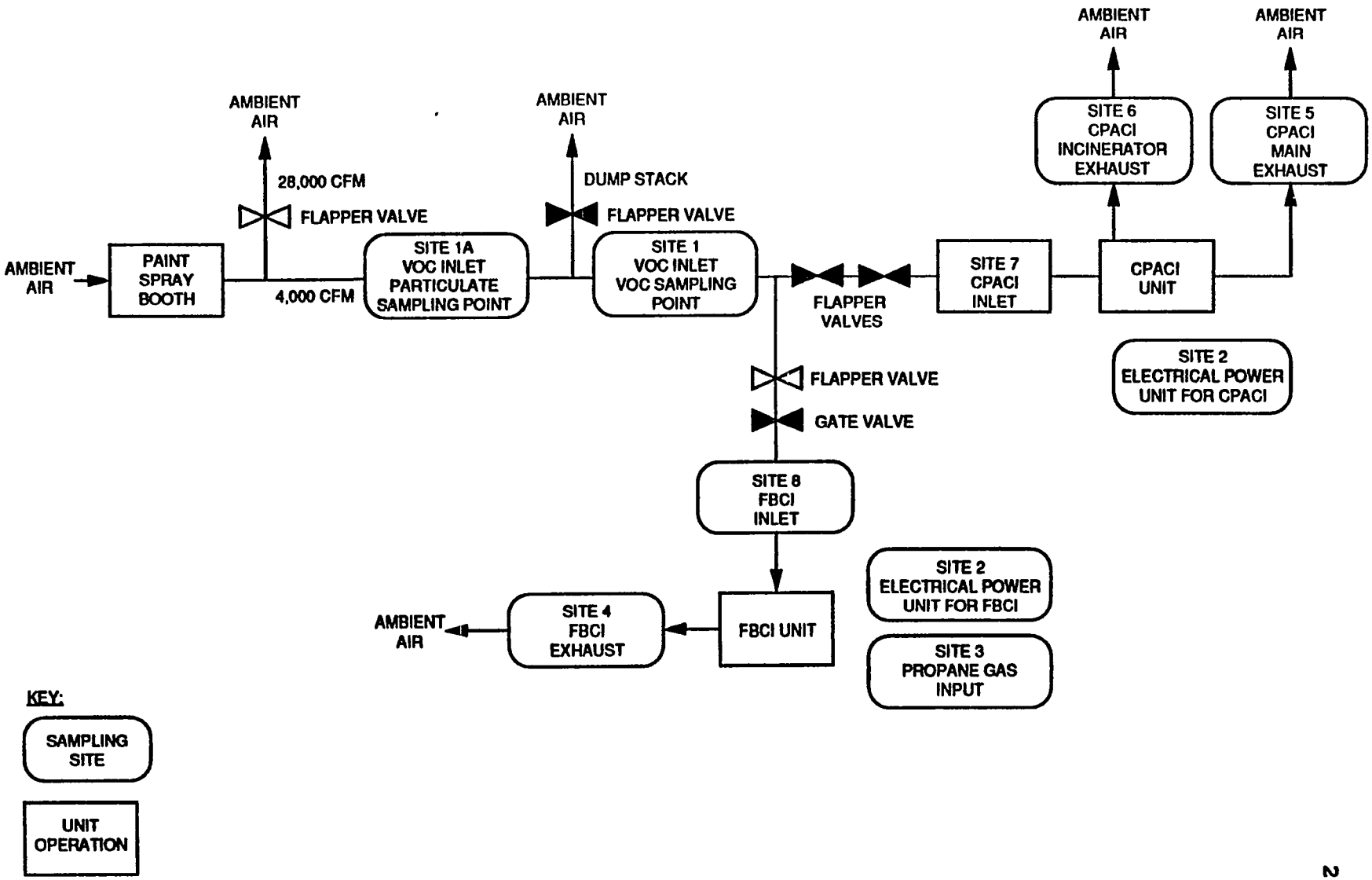


Figure 5. Configuration of Sampling Sites.

varied for the two different VOC control devices due to the design differences of these devices. Table 3 summarizes the desired operating conditions for both control devices.

The actual operating parameters obtained during the test program are summarized in Table 4. This table lists the dates and times that the tests were performed, whether the tests were for organic speciation or particulates and moisture, and the actual flowrates and temperatures obtained in both the CPACI and FBCI units during the test.

B. System Operation

The temperatures and flowrates were set according to the test matrix agreed upon by the EPA and Air Force Project Officers, the vendors, and the test crew chief. The FBCI unit was run by an Acurex field crew member after a day of training with the ARI Technologies, Inc. representative. The CPACI unit was run by a pilot engineer from the Met-Pro Corporation. Difficulties with the FBCI unit on Monday, May 15, were encountered which required a representative from ARI to fly out. The controller in the FBCI unit needed reprogramming in order to resume operation. This problem was resolved on Monday night.

TABLE 3. DESIRED OPERATING CONDITIONS.

Device	Operating Condition	Flow rate (dscfm)	Temperature (°F)
FBCI	High temperature/low flow rate	<450	>750
FBCI	Optimum temperature/optimum flow rate	450-550	650-750
FBCI	High temperature/high flow rate	>550	>750
CPACI	High temperature/low flow rate	<450	>650
CPACI	Optimum temperature/optimum flow rate	450-600	550-650
CPACI	High temperature/high flow rate	>600	>650

TABLE 4. CHRONOLOGICAL TEST SUMMARY.

Date	Time	Test Type	Run Number	CPACI Flow rate[a] (dscfm)	CPACI Temperature[a] (°F)	FBCI Flow rate[a] (dscfm)	FBCI Temperature[a] (°F)
5/10/89	0930-1030	M5	Test-1	300/340	650/640	500/466	700/698
5/10/89	0930-1010	NIOSH	Test-2	300/340	650/640	500/466	700/698
5/10/89	1300-1340	NIOSH	Test-3	500/507	650/665	400/348	950/950
5/10/89	1830-1930	M5	Test-2	500/503	650/625	400/446	950/950
5/10/89	1830-1910	NIOSH	Test-4	500/503	650/625	400/446	950/950
5/11/89	1030-1130	M5	Test-3	400/435	750/600-730	400/402	1250/1000
5/11/89	1035-1115	NIOSH	Test-5	400/435	750/660-730	400/402	1250/1000
5/11/89	1250-1330	NIOSH	Test-6	500/525	650/655-670	500/495	950/950
5/11/89	1655-1755	M5	Test-4	500/517	750/750	500/494	700/700
5/11/89	1700-1740	NIOSH	Test-7	500/517	750/750	500/494	700/700
5/12/89	0915-1015	M5	Test-5	500/529	650/650	500/535	1250/965-1027
5/12/89	0920-1000	NIOSH	Test-8	500/529	650/650	500/535	1250/965-1027
5/12/89	1235-1315	NIOSH	Test-9	600/535	650/660-675	600/691	950/809-805
5/15/89	1035-1135	M5	Test-6	600/626	650/650	Down	Down
5/15/89	1025-1050 1205-1215	NIOSH	Test-10	600/626	650/650	Down	Down
5/15/89	1250-1330	NIOSH	Test-11	700/700	750/750	Down	Down
5/15/89	1700-1800	M5	Test-7	600/601	750/750	Down	Down
5/15/89	1700-1740	NIOSH	Test-12	600/601	750/750	Down	Down
5/16/89	1035-1135	M5	Test-8	400/441	650/650	600/524	1250/1002
5/16/89	1035-1115	NIOSH	Test-13	400/441	650/650	600/524	1250/1002
5/16/89	1235-1315	NIOSH	Test-14	400/405	650/650	600/524	1250/1002
5/17/89	0910-1010	M5	Test-10	700/675	650/650	600/584	700/700
5/17/89	0915-0955	NIOSH	Test-16	700/675	750/650	600/584	700/700
5/17/89	1215-1255	NIOSH	Test-17	700/668	650/650	600/580	700/700
5/17/89	1815-1915	M5	Test-11	600/587	750/750	600/611	775/775
5/17/89	1815-1855	NIOSH	Test-18	600/587	750/750	600/611	775/775

TABLE 4. CHRONOLOGICAL TEST SUMMARY (CONCLUDED).

Date	Time	Test Type	Run Number	CPACI Flow rate[a] (dscfm)	CPACI Temperature[a] (°F)	FBCI Flow rate[a] (dscfm)	FBCI Temperature[a] (°F)
5/18/89	1035-1135	M5	Test-12	500/517	750/750	300/339	700/706-725
5/18/89	1040-1120	NIOSH	Test-19	500/517	750/750	300/339	700/706-725
5/18/89	1220-1320	M5	Test-13	400/393	750/750	300/297	550/550-557
5/18/89	1825-1905	NIOSH	Test-20	300/279	650/650	600/565	550/550
5/18/89	1840-1940	M5	Test-14	300/279	650/650	600/565	550/550
5/18/89	2115-2215	M5	Test-15	300/303	750/750	600/620	550/550
5/18/89	2120-2200	NIOSH	Test-21	300/303	750/750	600/620	550/550
5/19/89	1230-1330	M5	Test-16	700/715	750/750	300/328	500+/550-707[b]
5/19/89	1230-1310	NIOSH	Test-22	700/715	750/750	300/328	500+/550-707[b]
5/19/89	1345-1445	M5	Test-17	700/695	650/650	400/396	550/550
5/19/89	1345-1425	NIOSH	Test-23	700/695	650/650	400/369	550/550
5/19/89	1700-1740	NIOSH	Test-24	DID NOT TEST CPACI		600/570	600/595-510
5/19/89	1645-1745	M5	Test-18	DID NOT TEST CPACI		600/570	600/595-510

[a]Temperatures and flow rates are to be read as: Desired/Actual.
[b]Temperature was set initially at 500°F for 25 minutes, then ramped to 700°F for the remainder of the test.

The flowrates to both the CPACI unit and the FBCI unit were set manually. The VOC inlet stream to these two units was split into two 10-inch ducts which fed to the control devices. The duct feeding the FBCI unit had a gate valve which consisted of a steel plate that cut the duct cross-sectionally and could be moved up or down to increase or decrease the flow, respectively. The CPACI unit had a flapper valve for adjusting the flowrates. The flowrates were set by performing a velocity traverse using EPA Method 2 to determine the velocity of the gas stream in the duct. The valves would then be adjusted to increase or decrease the flow accordingly.

Another velocity traverse would then be performed to determine if the desired flowrate had been obtained. This procedure would continue until the flowrates to both units were set at the desired levels.

The temperature on the FBCI unit was controlled through a digital controller. The set point on the controller was entered into the controller by the operator as soon as the desired test conditions were known. The system would then take approximately 30 to 60 minutes to reach its desired temperature.

The temperature control on the CPACI was set manually by the Met-Pro pilot engineer. There were three

catalyst heating elements for this unit which were run on toggle switches for the "on" or "off" position. The ratings of these elements were 1KW, 3KW and 4KW. The engineer would manually monitor the temperature of the catalyst with a thermometer and turn on or shut off the elements accordingly. The Met-Pro engineer also set the carbon paper rotor speed based on the system flowrate. A system shutoff switch could be used to shut the system down at 650°F if desired.

C. Painting Schedule

The painting and sampling schedules were coordinated by the Acurex field crew members. A member of the field crew would be in close contact with the painters so that the field crew could be informed of when painting would occur. When it was determined that the painters were getting close to being ready, the crew member would alert the field crew. The painters would then shut the main doors to the paint spray booth so that the flowrates to the control devices could be set by the method previously described. This process would take up to 20 minutes, at which time the painting session could begin. The times of the painting sessions and the types of paints being used were recorded in the field notebook. Table 5 summarizes the color of paint used, the military

TABLE 5. PAINTING LOG.

Date	Color	Military Specification
5/10/89	Field Drab	MIL-C-46168D
5/10/89	Green 383 Camouflage	MIL-C-46168D
5/11/89	Wash Primer	GS-10F-51047
5/11/89	Deft Primer	MIL-85582A
5/11/89	Olive Drab	MIL-C-46168C
5/12/89	Green 383 Camouflage	MIL-C-46168D
5/15/89	Wash Primer	GS-10F-51047
5/15/89	Crown Metro Primer	MIL-P-85582A
5/16/89	Gray	unknown
5/16/89	Wash Primer	GS-10F-51047
5/16/89	Deft Primer	MIL-85582A
5/17/89	Deft Primer	MIL-85582A
5/17/89	383 Forest Green	MIL-C-46168D
5/17/89	Field Drab	MIL-C-46168D
5/18/89	Deft Primer	MIL-C-85582A
5/18/89	383 Forest Green	MIL-C-46168D
5/19/89	Field Drab	MIL-C-46168D
5/19/89	383 Forest Green	MIL-C-46168D
5/19/89	White	MIL-HS-8386

specification, and the date that the paint was used.

D. Test Method Descriptions

The sampling methods used during the test program are summarized in the sampling methods table in the Test Matrix section (Table 2). The EPA methods are described in detail in the Code of Federal Regulations and the Bay Area Method ST-7 is described in the Bay Area Air Quality Management District's Manual of Procedures.[6,7,8,10,11,12,13] The NIOSH method used is described in the NIOSH Manual of Analytical Methods.[9]

Volume flow data were taken using EPA Method 2. In this method, the average gas velocity in the stack is determined from the gas density and from measurement of the average velocity head with a standard pitot tube or a Type S pitot tube. The temperature and static pressure were determined in each duct or stack and the barometric pressure was recorded. Two perpendicular traverses of 5 points each were made through the duct to record pressure drops. An inclined manometer or a magnehelic gauge was used to measure these pressure drops. All the information obtained was then entered into a computer spreadsheet that utilized the calculations outlined in EPA Method 2. The spreadsheet was used to calculate the average flowrate in the duct.

Organic speciation data were obtained by following NIOSH Method 1300 sample collection procedures. This method involves drawing a known volume of gas through a charcoal absorbent contained in a glass tube (charcoal tube). The charcoal is then desorbed with a solvent appropriate for the class of compounds under study, and the extract is analyzed by gas chromatography/flame ionization detection (GC/FID). Two charcoal tubes were connected in series to ensure complete sample capture in case breakthrough occurred in the upstream tube. The NIOSH 1300 method specifies the use of a 100-mg/50-mg charcoal tube (100 mg of charcoal in the front section and 50 mg of charcoal in the back section). However, two sizes of charcoal tubes were used during this test. At the VOC emission control inlet (Site 1) a larger, 400-mg/200-mg, tube was used; at the FBCI exhaust, CPACI carbon paper exhaust, and the CPACI incinerator exhaust, 100-mg/50-mg charcoal tubes were used. Sample volumes of 8 liters each were pulled from the incinerator exhaust streams and 40-L samples were pulled from the VOC inlet stream.

EPA Method 5 was used to measure particulate mass and moisture in the stack gas. This is an isokinetic sampling method that entails a multipoint duct traverse to collect a known volume of sample gas. The gas sample

is pulled through a preweighed filter that collects the particulate matter. The gas is then pulled through a series of four impingers to collect any moisture in the gas stream. The gas volume is accurately measured by a dry gas meter. The front half of the sampling train, which contains the preweighed filter, is heated to avoid condensation on the filter. The back half of the train contains the impingers in an ice bath to promote condensation of any liquid in the gas stream. These impingers may contain liquid, silica gel, or be empty. All the impingers are tared before they are used and weighed after the sampling event. The increase in weight, attributed to moisture collection, can then be used to calculate the moisture content of the gas stream. The filter is desiccated and reweighed to determine the particulates collected. Figure 6 is a schematic of a Method 5 sampling train.

In this test series, the first two impingers each contained 100 mL of distilled water. The third impinger was dry and the fourth impinger contained silica gel. A gas sample volume of approximately 60 ft^3 was collected during each of these tests. Two perpendicular, 30-min traverses were performed across the cross section of the VOC emission control inlet ducting (Site 1A). Two 30-min traverses on one axis were performed at the FBCI

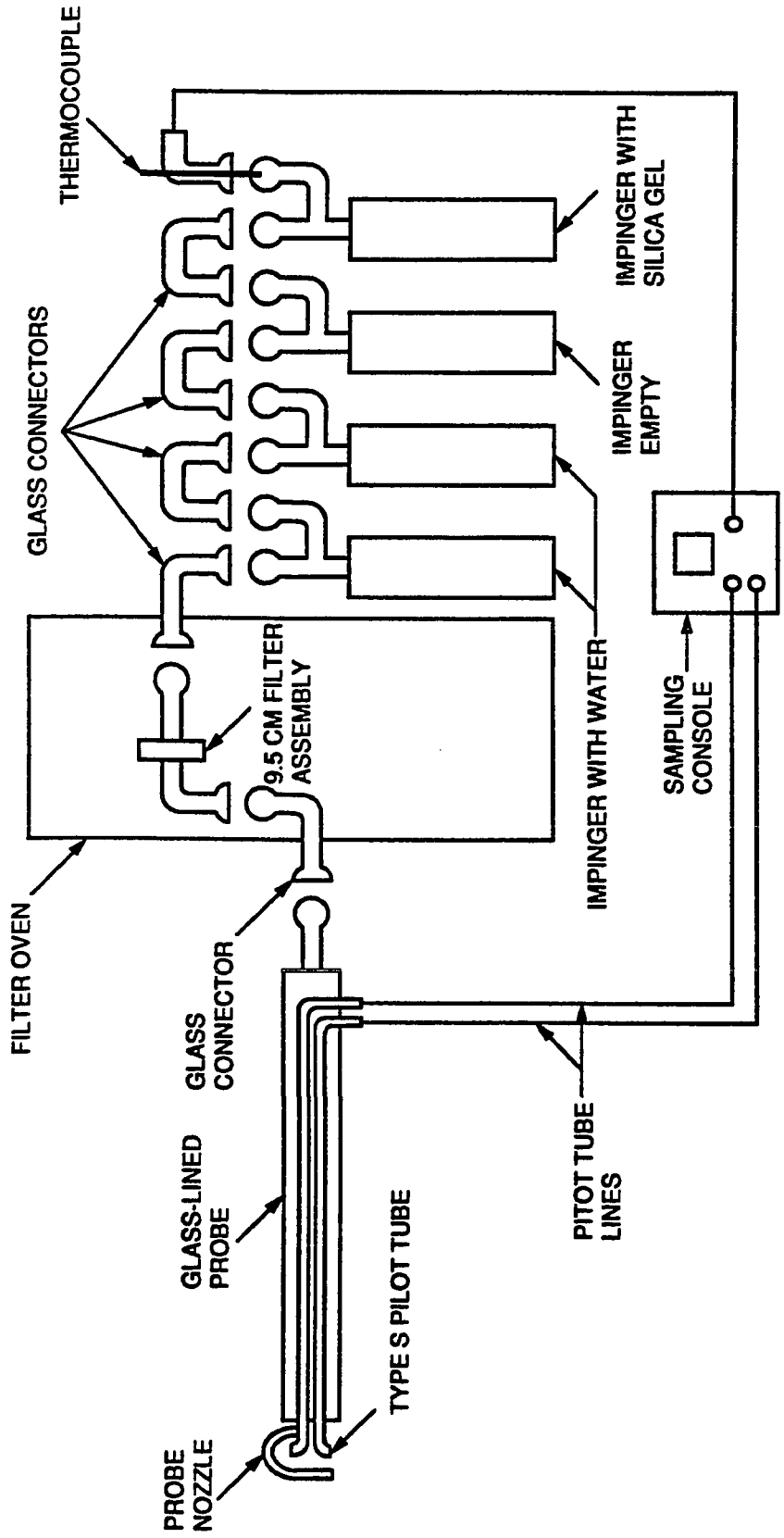


Figure 6. Schematic of EPA Method 5 Sampling System.

exhaust stack because only one sampling port existed on the stack. A single-point sample was pulled at the CPACI incinerator exhaust stack due to the configuration of the stack. This stack diameter was only 4 inches, which made multipoint sampling impractical.

Moisture content was measured at the FBCI exhaust, CPACI carbon paper exhaust, and the CPACI incinerator exhaust, when Method 5 data was not obtained. EPA Method 4 was used to obtain this information. This method requires single-point sampling using one empty impinger and one silica gel impinger.

Electricity consumption was measured using a standard watt-hour meter. Propane consumption was measured with a standard dry gas meter. These data were recorded in the field notebook. Inlet hydrocarbons were analyzed continuously using the Bay Area Air Quality Management District Method ST-7. The continuous emissions monitor used was a Beckman 400. This unit uses a nondispersive infrared (NDIR) analyzer to measure CO_2. It measures the carbon concentration in a gas stream as CO_2 after the carbon has been oxidized. Organic carbon in the gas stream being analyzed is oxidized to CO_2 by a tube furnace.

Continuous emission monitoring was performed on the FBCI exhaust and the CPACI incinerator exhaust.

Hydrocarbon concentrations were monitored continuously at the exhaust outlets during testing by EPA Method 25A. This method draws a sample through a heated line to a flame ionization detector. The detector is intermittently zeroed and spanned with zero air and a methane standard, respectively. Two units were used to monitor total unburned hydrocarbons at the FBCI exhaust and the CPACI incinerator exhaust. These units were a Rattfisch and a Horiba F1A-23A, both of which contain a flame ionization detector.

One set of instruments was alternately used to performed O_2, CO, CO_2, and NO_x testing. Oxygen concentrations were monitored with the Teledyne Analytical 326A monitor which uses an electrochemical fuel cell. Carbon monoxide levels were measured with a Horiba PIR-2000 NDIR detector. Carbon dioxide levels were monitored with an ANRAD AR500 which also uses a NDIR detector. Nitrogen oxides were measured with a Thermo Electron Corp 10AR monitor that uses chemiluminescence as its principal of operation. These monitoring instruments were shared between the two incinerator exhaust streams.

E. Field Comments

The following list of items summarizes the field comments regarding the testing:

- The Method 5 sampling for the CPACI incinerator exhaust was modified from a traverse method to a single-point method because the duct size was 4 inches and could not be traversed. The probe nozzle represents a significant area of the duct.

- The sampling port on the FBCI was not within the 8-diameter and 2-diameter specifications outlined in the Code of Federal Regulations; thus an increased number of sample traverse points was used, per EPA Method 1.

- Flow measurements on the CPACI carbon paper exhaust are suspect because of the turbulence observed in the rectangular exhaust duct. It was assumed therefore that the inlet flowrate to the CPACI equaled the outlet flowrate from the carbon paper exhaust.

- Flowrates of exhaust from the paint spray booth were variable on May 12th and part of May 13th. The configuration of the ductwork on top of Building 655 allowed an unusual northeast wind to blow into the ducting. Fluctuations of as much as 100 cfm were noted on two occasions. The problem was solved by placing a wind screen over the exposed ductwork opening.

CHAPTER IV

RESULTS AND DISCUSSION: TECHNOLOGY PERFORMANCE EVALUATION

To evaluate each technology, it was necessary to calculate DREs and pollutant emission rates for each test. Power consumption of each unit for each testing period was also determined. Results of these tests were then grouped according to the three test conditions described in the work plan.[14] These conditions are low flowrate/high temperature, optimum flowrate/optimum temperature, and high flowrate/high temperature. Table 6 explains the flowrate and temperature values associated with each condition. Subsection A contains the results of the paint spray booth emissions testing. Subsections B and C present the results for the VOC control devices. Discussions of the test results are also presented in each subsection.

A. Description of Exhaust From Paint Spray Booth

The VOC-contaminated air stream from the paint spray booth was sampled to establish particulate concentration and hydrocarbon levels. NIOSH sampling was also performed to speciate the VOCs present. Table 7

TABLE 6. TABLE OF TEST CONDITIONS.

Test Conditions (No.)	CPACI		FBCI	
	Flow Rate (dscfm)	Temperature (°F)	Flow Rate (dscfm)	Temperature (°F)
Low flow rate/high temperature (1)	<450	>650	<450	>750
Optimum flow rate/optimum temperature (2)	450-600	550-650	450-550	650-750
High flow rate/high temperature (3)	>600	>650	>550	>750

TABLE 7. PAINT SPRAY BOOTH EXHAUST PARTICULATE RESULTS.

Date	Run Number	Particulate Emissions	
		gr/dscf	lb/hr
5/10/89	M5-01	0.0018	0.02
5/10/89	M5-02	0.0006	0.01
5/10/89	M5-03	0.0018	0.02
5/11/89	M5-04	0.0011	0.01
5/12/89	M5-05	0.0015	0.02
5/15/89	M5-06	0.0038	0.04
5/15/89	M5-07	0.0044	0.05
5/16/89	M5-08	0.0040	0.05
5/16/89	M5-09	0.0020	0.03
5/17/89	M5-10	0.0009	0.01
5/17/89	M5-11	0.0002	0.003
5/17/89	M5-12	0.0015	0.02

summarizes the particulate results. Particulate concentration was low, with a maximum value of 0.0044 gr/dscf (grains/dry standard cubic foot). The average particulate concentration was 0.002 gr/dscf. Table 8 identifies the VOCs present at detectable levels. The most frequently seen compound was 2-butanone (MEK). CEM results for inlet hydrocarbon levels are presented in Appendix A (Table A-1). The concentration of hydrocarbons varied, as is expected for the batch nature of the spray painting that generates the air emissions. The maximum concentration of hydrocarbon observed, as organic carbon, was 752 ppmv. Minimum levels recorded were 30 ppmv. Hydrocarbon readings averaged 132.5 ppmv.

There was a correlation between hydrocarbon levels and the type of work being performed in the paint spray booth. When wash primer was being sprayed, hydrocarbon levels generally ranged from 30 to 45 ppmv. Higher levels were detected when top coats were being sprayed. The highest hydrocarbon levels were measured when MEK was sprayed directly into the paint booth exhaust stream.

B. Carbon Paper Adsorber/Catalytic Incinerator

VOC emissions from Paint Booth 665 were vented to the CPACI. Flow into the unit was monitored and adjusted as necessary. The CPACI was tested at both emission

TABLE 8. VOCs DETECTED.

Organic Chemicals Present At Detectable Quantities	Paint Spray Booth Exhaust	CPACI Carbon Paper Exhaust	CPACI Incinerator Exhaust	FBCI Exhaust
2-Butanone	X	X	X	
Ethyl acetate				
Methoxyacetone	X		X	
4-methyl-2-pentanone	X			
Toluene	X		X	X
Butyl acetate	X		X	
Ethylbenzene	X		X	
p-Xylene	X			
o-Xylene	X			
2-ethoxyethyl acetate	X			
2-methoxyethoxy ethanol	X			

points -- the main exhaust (carbon paper) and the incinerator exhaust. Table 9 summarizes the test results for the CPACI.

1. Method 5 Results

EPA Method 5 test results for the CPACI are presented in Table 10. Particulate concentration (gr/dscf) and particulate mass emission rate (lb/hr) were both very low for all tests performed. The highest concentration found was 0.0057 gr/dscf. The maximum mass emission rate was 0.0025 lb/hr. Both occurred during a test in which the operating temperature was 650°F and the influent flowrate was 529 dscfm. Minimum particulate concentration and mass emission rates were 0.0001 gr/dscf and 0.0001 lb/hr. These occurred when the operating temperature was 625°F and the influent flowrate was 503 dscfm. The average particulate concentration was 0.002 gr/dscf. The average particulate mass emission rate was 0.0007 lb/hr. These averages include results gathered from sampling the CPACI over a wide range of operating conditions.

2. NIOSH 1300 Test Results

NIOSH tests were performed at the carbon paper exhaust and at the incinerator exhaust. Results of the

TABLE 9. CARBON PAPER ADSORPTION/CATALYTIC INCINERATOR RESULTS SUMMARY.

Run No.[a]	Temperature (°F)	Inlet Flow Rate (dscfm)	Incinerator Exhaust (dscfm)	Main Exhaust (dscfm)	Unit DRE (%)	Organic Emissions (lb VOC/hr)	Particulate Emissions (lb/hr)	Power Usage (Btu/hr)	Power/VOCs Destroyed Ratio (MMBtu/lb VOC destroyed)
Test-2	640	340	35	340	--	--	0.0001	--	--
Test-3	665	507	40	507	99.4	0.00098	--	28,300	0.17
Test-4	625	503	40	503	99.6	0.0012	0.0001	43,900	0.15
Test-5	660-730	435	39	435	99.6	0.00041	0.0006	31,600	0.28
Test-6	665-670	525	38	525	>99.6	0.00040	--	31,900	0.35
Test-7	750	517	40	517	>98.8	0.00045	0.0016	--	--
Test-8	650	529	40	529	>99.5	0.00085	0.0025	8,500	0.050
Test-9	660-675	535	42	535	>96.9	0.0013	--	34,200	0.83
Test-10	650	626	42	626	98.8	0.0075	0.0001	--	--
Test-11	750	700	28	700	>98.6	0.0020	--	23,800	0.33
Test-12	750	601	41	601	>99.6	0.00055	0.0011	40,700	0.31
Test-13	650	441	39	441	>99.1	0.00043	0.0008	37,600	0.20
Test-14	650	405	38	405	98.1	0.00066	--	37,600	0.21
Test-16	650	675	43	675	>99.5	0.00072	0.0004	51,200	0.90
Test-17	650	668	43	668	>99.7	0.00072	--	34,200	0.44
Test-18	750	587	33	587	>99.8	0.00052	0.0003	39,800	0.80
Test-19	750	517	41	517	>99.1	0.00045	0.0003	37,600	0.79
Test-20	650	279	32	279	>98.9	0.00028	--	34,800	0.37
Test-21	750	303	27	303	>99.7	0.00023	--	27,000	0.27
Test-22	750	715	44	715	>99.8	0.00041	--	49,000	0.034
Test-23	650	695	41	695	--	--	--	43,600	--

[a]Test-1 was a background test
-- = Not available.

TABLE 10. CPACI: PARTICULATE RESULTS.

Date	Run Number	Flow Rate (dscfm)	Temperature (°F)	Particulate Emissions	
				gr/dscf	lb/hr
5/10/89	M5-01	340	640	0.0002	0.0001
5/10/89	M5-02	503	625	0.0001	0.0001
5/10/89	M5-03	435	660-730	0.0017	0.0006
5/11/89	M5-04	517	750	0.0047	0.0016
5/12/89	M5-05	529	650	0.0057	0.0025
5/15/89	M5-06	626	650	0.0003	0.0001
5/15/89	M5-07	601	750	0.0037	0.0011
5/16/89	M5-08	441	650	0.0027	0.0008
5/17/89	M5-10	675	650	0.0014	0.0004
5/17/89	M5-11	587	750	0.0010	0.0003
5/18/89	M5-12	517	750	0.0011	0.0003

analyses of charcoal tubes collected at these points were used to speciate the organic compounds in the exhaust of the CPACI. NIOSH tests were not performed on the CPACI for the purpose of quantifying the VOC emissions.

Samples collected at the carbon paper adsorber exhaust point consistently contained VOC levels below the sensitivity of the analytical technique (0.1 to 10 ppb). Only 2 of 23 tests run showed any measurable VOCs. Tests 10 and 23 showed MEK. NIOSH charcoal tubes collected at the CPACI incinerator exhaust had measurable quantities of VOCs in 16 of the 23 tests performed. The organic compound found most frequently was MEK. MEK was also the VOC found at the highest concentrations. Other compounds found are listed in Table 8. Laboratory analytical reports and tables of VOC concentrations found during each test are not included here because of their length. They can be obtained from the Environmental Systems Division, Acurex Corporation.

3. Results of Continuous Emissions Monitoring

EPA Method 25A was used to measure the total unburned hydrocarbon (TUHC) from both emission points of the CPACI. Table 11 lists the TUHC results for the CPACI. The TUHC measurements from the carbon paper adsorber were usually below the detectable limit of

TABLE 11. CPACI: TUHC RESULTS.

Date	Run Number	Actual Flow Rate (dscfm)	Actual Temperature (°F)	TUHC Carbon Bed (ppmv)	TUHC Incinerator (ppmv)
5/10/89	Test-2	340	640	--	0.5
5/10/89	Test-3	507	665	--	27.9
5/10/89	Test-4	503	625	--	33.1
5/11/89	Test-5	435	660-730	0.6	5.2
5/11/89	Test-6	525	665-670	0.5	7.6
5/11/89	Test-7	517	750	0.5	6.9
5/12/89	Test-8	529	650	0.5	17.3
5/12/89	Test-9	535	660-675	0.5	29.6
5/15/89	Test-10	626	650	6.7	47.2
5/15/89	Test-11	700	750	0.5	53.0
5/15/89	Test-12	601	750	0.5	7.7
5/16/89	Test-13	441	650	0.5	6.7
5/16/89	Test-14	405	650	1.4	4.4
5/17/89	Test-16	675	650	0.5	11.7
5/17/89	Test-17	668	650	0.5	11.8
5/17/89	Test-18	587	750	0.5	7.6
5/18/89	Test-19	517	750	0.5	2.3
5/18/89	Test-20	279	650	0.5	3.9
5/19/89	Test-21	303	750	--	4.2
5/19/89	Test-22	715	750	0.5	1.9
5/19/89	Test-23	695	650	--[a]	--[a]

[a]Unit overheated.
-- = Not available.

0.5 ppmv. On May 15, 1989 during the NIOSH test number 10 (NIOSH-10), the TUHC level was 6.7 ppmv. TUHC measurements made at the CPACI incinerator exhaust were below 10 ppm for over 65 percent of the tests. Maximum values seen were 53 and 47.2 ppmv. The minimum values found were 1.9 ppmv and a measurement that was below the detectable limit.

4. Destruction and Removal Efficiencies (DREs)

The results of the NIOSH 1300 tests and the CEM measurements were used to calculate DREs for the CPACI. DREs were calculated for both CPACI emission points and for the unit as a whole. Table 9 displays the DREs for the whole CPACI. Thirteen of the 19 DREs calculated were greater than 99 percent. Five of the remaining calculated DREs were greater than 98 percent. The remaining DRE was the lowest one, >96.9 percent. The "greater than" sign signifies that the hydrocarbon emission levels were below detectable levels. DRE calculations were made using the minimum detection level achievable for TUHC, 0.5 ppmv. This procedure enables a minimum DRE to be calculated. Thus, the representation of these values as, for example, " >96.9 percent".

Removal efficiencies for the CPACI carbon paper rotor are presented in Appendix B; Table B-2 shows that

the paper rotor achieved removal efficiencies of >99 percent for all tests performed except one. That exception had a removal efficiency of 98.5 percent.

DREs for the CPACI incinerator are also presented in Table (B-2) of Appendix B. The DREs were generally better than 99 percent. Two values were lower than 99 percent. The DRE for the testing event NIOSH-9 was 97.4 percent. DRE during the testing event NIOSH-11 was 98.8 percent.

5. Power Consumption

Power consumption by the CPACI is summarized in Table 9. Consumption rates that were calculated for each test are reported in Btu/hr to standardize the data. The rates ranged from a low of 8,538 Btu/hr to a high of 51,225 Btu/hr. The low occurred during a test in which the unit was operating at a temperature of 650°F and an influent flowrate of 529 dscfm (Test #8, Table 9). The highest rate occurred when the system was operating at a temperature of 650°F and 675 dscfm.

Power consumption of the CPACI was also evaluated on a daily basis. Table 12 presents these data. Daily power usage numbers average the many conditions under which the CPACI was operating each day. The maximum

TABLE 12. DAILY POWER USAGE TOTALS.

Date	CPACI Unit				FBCI Unit		
	Time (hr)	Power Used (kW-hr)	Rate of Usage (kW)	Rate of Usage (Btu/hr)	Time (hr)	Propane Used (cu. ft)	Rate of Usage (Btu/hr)
5/08/89	Unit	----------Shut Down----------			7.05	1460	473,000
5/09/89	7.42	80.00	10.78	36,800	8.00	1310	374,000
5/10/89	9.92	101.00	10.18	34,800	13.10	2500	436,000
5/11/89	9.00	101.50	11.28	38,500	10.90	2240	469,000
5/12/89	5.50	84.25	15.32	52,300	5.78	1660	656,000
5/15/89	3.30	23.00	6.97	23,800	13.50	2750	465,000
5/16/89	13.75	150.50	10.95	37,400	12.50	2580	471,000
5/17/89	13.50	166.50	12.33	42,100	13.50	2640	446,000
5/18/89	11.95	112.00	9.37	32,000	7.75	1300	383,000
5/19/89	8.02	187.50	23.38	79,800	9.36	1220	298,000

power consumption occurred on May 19, 1989, when the rate of usage was 79,800 Btu/hr.

6. Discussion

Particulate concentration from the CPACI averaged 0.002 gr/dscf. This concentration is below the EPA level of 0.08 gr/dscf. Examination of the particulate data in Table 10 reveals a lack of relationship between the flowrate and particulate concentration or between temperature and particulate concentration. The CPACI design does not contribute to particulate emissions. The solvent laden air is prefiltered to remove any particulate matter. Exhaust from the carbon paper rotor was, therefore, not expected to have any particulate matter and was not subjected to Method 5 sampling. The CPACI incinerator exhaust was also not expected to have a significant concentration of particulate matter. Air flowrate to the incinerator is very low, between 30 and 70 dscfm. This air is ambient air and presumably low in particulate concentration. These factors contribute to the very low particulate concentration and emission rate from the CPACI incinerator flue gas and the whole CPACI.

NIOSH test results were combined with the CEM hydrocarbon data to determine the mass emission rate of VOCs for the CPACI. Organic emissions for each test are

listed in Table 9. The largest emission rate was 0.0075 lb/hr of VOCs. This happened during a period of highest solvent loading to the unit, 0.641 lb/hr VOCs. The CPACI was operating at 650°F and 626 dscfm. These operating parameters are at the upper end of the pilot-scale unit's temperature and flowrate ranges of 625°F and 700 dscfm. Exhaust from the carbon paper adsorber contained most of the solvent loading in this case, 0.005 lb/hr. This test, NIOSH-10, was the only test in which a noticeable hydrocarbon concentration was found in the carbon paper adsorber exhaust. During this test period, MEK was sprayed directly into the exhaust ducts of the paint spray booth. There was a resultant hydrocarbon spike of 69 ppmv in the carbon paper exhaust. The implication is that the carbon paper rotor may be spent by a high VOC concentration in a volume of air moving through the system in a plug flow fashion. Overall, the CPACI had very low organic emissions rates as seen in Table 9.

The main reason for the low VOC emission rates appears to be the consistent 98 percent to 99 percent DREs that the CPACI achieved. Review of the data in Table 9 shows that 98 percent and 99 percent DREs were consistently obtained by the CPACI under a variety of operating conditions. No significant correlations could be made between DREs, operating temperatures and

flowrates. Even during periods of heavier solvent loading and high flowrates DREs were greater than 98 percent.

Power usage for the CPACI appears to be low. This is expected since only 30 to 70 dscfm of air needs to be heated. The air that is heated contains concentrated VOCs which can add energy to the system when combusted. There are also no correlations between influent flowrate and power usage. Since the energy being used is heating the desorption air and not the whole influent gas, this is expected. There is a relationship between Btu/hr and desorption air flowrate as can be seen from the data in Table 9. (The incinerator exhaust flowrate is the same flowrate as the desorption air flowrate.) When the desorption air flowrate was between 30 and 45 dscfm, the power consumption was usually greater than 30,000 Btu/hr. During tests in which the desorption air flowrate was less than 30 dscfm, then the power consumption was less than 30,000 Btu/hr.

Temperature comparisons with power usage do not show a general trend of increasing power consumption with increasing operating temperature. This is probably a result of not having enough data points to adequately evaluate the relationship. The CPACI was operated mainly at three temperatures, 625°F, 650°F, and 750°F.

Power consumption information was combined with data regarding the mass of VOCs destroyed to calculate a ratio of power consumed per pound of VOCs destroyed (MMBtu/lb VOC destroyed). These ratios are shown for each test in Table 9. Table 13 shows the Power/VOCs Destroyed Ratio (PVDR) values by test condition, solvent loading and power usage. PVDRs are relevant for comparison purposes when solvent waste stream loading is similar. Within these constraints, the loading into the CPACI was similar, on the average, for two operating conditions. These conditions, Test Condition 1 and Test Condition 2, correspond to high temperature/low flow and optimal temperature/optimal flow (manufacturer suggested) parameters. Respective PVDRs for these two conditions are 0.38 and 0.29 MM Btu/lb VOC Destroyed. Since the CPACI was operating at a lower temperature during Test Condition 2, it is expected that less power was being used. Operating the CPACI under optimal conditions used less power to destroy the same amount of VOCs compared with operating the system at higher temperatures. However, the DRE under both conditions is the same. Tables 14 and 15 show that the DREs for both operating conditions are >99 percent.

Tables 14 through 16 average the test results for the sampling events that happened during specific test

TABLE 13. CPACI: POWER/VOCs DESTROYED RATIOS.

Date	Run No.	Test Condition No.[a]	Inlet (lb VOC/hr)	Outlet (lb VOC/hr)	VOCs Destroyed (lb VOC/hr)	Fuel Usage Rate (Btu/hr)	Power/VOCs Destroyed Ratio (MMBtu/lb VOC Destroyed)
5/10/89	Test-3	2	0.16	0.00098	0.16	28,200	0.17
5/10/89	Test-4	2	0.29	0.0012	0.29	43,900	0.15
5/11/89	Test-5	1	0.11	0.00041	0.11	31,600	0.28
5/11/89	Test-6	2	0.094	0.00040	0.094	31,900	0.34
5/12/89	Test-8	2	0.17	0.00085	0.17	8,540	0.049
5/12/89	Test-9	2	0.042	0.0013	0.041	34,200	0.84
5/15/89	Test-11	3	0.073	0.0020	0.071	23,800	0.34
5/15/89	Test-12	3	0.13	0.00055	0.13	40,700	0.31
5/16/89	Test-13	2	0.18	0.00043	0.18	37,600	0.21
5/16/89	Test-14	1	0.18	0.00066	0.18	37,600	0.21
5/17/89	Test-16	3	0.057	0.00072	0.056	51,200	0.91
5/17/89	Test-17	3	0.077	0.00072	0.076	34,200	0.45
5/17/89	Test-18	3	0.050	0.00052	0.049	39,300	0.81
5/18/89	M5-13	1	0.048	0.00045	0.048	37,600	0.79
5/18/89	Test-20	1	0.094	0.00028	0.094	35,000	0.37
5/18/89	Test-21	1	0.10	0.00023	0.10	27,000	0.27
5/19/89	Test-22	3	1.5	0.00041	1.5	49,000	0.034
5/19/89	Test-23	3	0.39	NA	NA	43,600	NA

[a]Test Conditions:
1. Low flow rate/high temperature (<450 dscfm, >650°F).
2. Optimum flow rate/optimal temperature (450 to 600 dscfm, 550 to 650°F).
3. High flow/high temperature (>600 dscfm, >650°F).

NA -- Not available.

TABLE 14. TEST AVERAGES: CPACI TEST CONDITION 1[a].

Date/ Time	Run Number	Flow Rate (dscfm)	Temp. (°F)	Rate of Usage (Btu/hr)	DRE (%)	Particulate Emissions (lb/hr)
5/11/89 1030-1130	Test-5	435	695	31,600	99.6	0.0006
5/16/89 1235-1315	Test-14	405	650	37,600	98.1	NA
5/18/89 1220-1320	M5-13	393	750	37,600	98.7	NA
5/18/89 1840-1940	Test-20	279	650	34,800	>98.9	NA
5/18/89 2115-2215	Test-21	303	750	27,000	>99.7	0.0003
Average:		363	699	33,700	>99.0	0.00045

[a]Low flow rate/high temperature (<450 dscfm, >650°F).
NA -- Not available.

TABLE 15. TEST AVERAGES: CPACI TEST CONDITION 2[a].

Date/ Time	Run Number	Flow Rate (dscfm)	Temp. (°F)	Rate of Usage (Btu/hr)	DRE (%)	Particulate (lb/hr)
5/10/89 1300-1340	Test-3	507	665	28,200	99.4[b]	NA
5/10/89 1830-1930	Test-4	503	625	43,900	99.6[b]	0.0001
5/11/89 1250-1330	Test-6	525	663	31,900	>99.6	NA
5/12/89 0920-1000	Test-8	529	650	8,540	>99.5	0.0025
5/12/89 1235-1315	Test-9	535	668	34,200	>96.9	NA
5/16/89 1035-1135	Test-13	441	650	37,600	>99.1	0.0008
Average:		507	654	30,700	>99.0	0.001

[a] Optimum flow rate/optimal temperature (450 to 600 dscfm, 550 to 650°F).
[b] Number reflects CPACI incinerator DRE only; the CPACI carbon paper exhaust was not monitored.
NA -- Not available.

TABLE 16. TEST AVERAGES: CPACI TEST CONDITION 3[a].

Date/ Time	Run Number	Flow Rate (dscfm)	Temp. (°F)	Rate of Usage (Btu/hr)	DRE (%)	Particulate Emissions (lb/hr)
5/15/89 1230-1330	Test-11	700	750	23,800	>98.6	NA
5/15/89 1700-1800	Test-12	601	750	40,700	>99.6	0.001
5/17/89 0920-1010	Test-16	675	650	51,200	>99.5	0.0004
5/17/89 1215-1255	Test-17	668	650	34,200	>99.7	NA
5/17/89 1815-1915	Test-18	587	750	39,800	>99.8	0.0003
5/19/89 1230-1330	Test-22	715	750	49,000	>99.8	NA
Average:		658	717	39,800	>99.5	0.0006

[a]High flow rate/high temperature (>600 dscfm, >650°F).
NA -- Not available.

conditions, Test Condition 1, Test Condition 2, and Test Condition 3. Comparison of the three tables elicits the following observations. Fuel usage was lowest for tests run at optimal temperature and flowrate conditions. Particulate mass emission rates are 0.001 lb/hr or less for each condition. Organic mass emission rates, although low, increased from Test Condition 1 to Test Condition 3. This is expected since Test Condition 1 reflects a best destruction situation, lower solvent loading and high temperature. Test Condition 3 characterizes a worst performance condition, high loading of the carbon paper adsorber. Despite the different operating conditions, DREs for all Test Conditions were greater than 99 percent.

The carbon paper adsorber/catalytic incinerator, at the pilot scale, does not have any significant pollutant emissions and can consistently achieve DREs in the 98 percent and 99 percent range. Operating temperatures and desorption flowrates do effect power consumption. Power consumption in general is low for this treatment technology. Concentration of the solvent wastes into a smaller air stream reduces the power needed for satisfactory destruction.

C. Fluidized-Bed Catalytic Incinerator

VOC emissions from Paint Booth 665 were vented to the Fluidized-Bed Catalytic Incinerator (FBCI). Monitoring was performed at the VOC inlet and at the FBCI exhaust. Flowrates were monitored at each of these points. FBCI test results are summarized in Table 17.

1. Method 5 Results

EPA Method 5 test results for the FBCI are summarized in Table 18. In general, particulate concentration (gr/dscf), and particulate mass emission rate (lbs/hour) were found to be below RCRA specifications (0.08 gr/dscf). Test M5-05 (NIOSH-8) had the maximum particulate emission rate of 0.23 lbs/hour with a concentration of 0.035 gr/dscf. FBCI flowrates and temperatures for this test were 535 dscfm and a range of 965 to 1027°F. The minimum particulate mass loading and concentration occurred during Test M5-12 and were 0.01 lbs/hr and 0.015 gr/dscf, respectively. In this case the system was operating under a flowrate of 339 dscfm, and a temperature range of 706 to 725°F.

2. NIOSH 1300 Test Results

NIOSH 1300 tests were performed at the FBCI exhaust for all runs, with the exception of Test M5-13. Results

TABLE 17. FLUIDIZED BED CATALYTIC INCINERATOR RESULTS SUMMARY.

Run No.[a]	Temperature (°F)	Inlet Flow Rate (dscfm)	Outlet Flow Rate (dscfm)	Unit DRE (%)	Organic Emissions (lb VOC/hr)	Particulate Emissions (lb/hr)	CO (ppmv)	NO_x (ppmv)
Test-2	698	466	720	99.0	0.0013	0.01	43	10.7
Test-3	950	348	543	>99.8	0.00024	--	58	19.3
Test-4	950	446	543	>99.9	0.00024	0.03	56	10.7
Test-5	1000	402	553	>99.8	0.00025	0.07	45	--
Test-6	950	495	679	>99.7	0.00025	--	--	--
Test-7	700	494	679	>99.2	0.00029	0.10	16	--
Test-8	965-1027	535	773	>99.8	0.00035	0.23	21	--
Test-9	809-805	691	948	>99.2	0.00042	--	40	--
Test-13	1002	524	684	99.2	0.00053	0.12	19	20.0
Test-14	1002	524	684	>99.3	0.00038	--	--	--
Test-16	700	584	794	>99.7	0.00036	0.14	75	12.3
Test-17	700	580	794	>99.9	0.00037	--	--	--
Test-18	775	611	794	99.2	0.0022	0.20	99	11.3
Test-19	706-725	339	438	>99.3	0.00019	0.01	37	11.8
M5-13	550-557	279	423	98.7	0.00043	0.02	68	9.9
Test-20	550	565	726	97.7	0.0011	0.11	68	10.1
M5-14	550	565	726	99.4	0.0011	0.11	68	10.1
Test-21	550	620	771	99.7	0.00056	0.12	90	9.0
Test-22	550-707	328	638	>99.7	0.00029	0.04	59	11.6
Test-23	550	369	639	99.6	0.0033	0.04	110	8.4
Test-24	595-510	570	723	99.8	0.00081	0.05	88.6	7.0

[a]Test-1 was a background test. The FBCI was not operational during Tests-10, -11, and -12. Test-15 was not used due to sporadic painting.
-- = Not available.

TABLE 18. FBCI: PARTICULATE RESULTS.

Date	Run Number	Flow Rate (dscfm)	Temperature (°F)	Particulate Emissions	
				gr/dscf	lb/hr
5/10/89	M5-01	466	698	0.0021	0.01
5/10/89	M5-02	446	950	0.0073	0.03
5/10/89	M5-03	402	1000	0.014	0.07
5/11/89	M5-04	494	700	0.017	0.10
5/12/89	M5-05	535	965-1027	0.035	0.23
5/16/89	M5-08	524	1002	0.021	0.12
5/17/89	M5-10	584	700	0.021	0.14
5/17/89	M5-11	661	775	0.029	0.20
5/18/89	M5-12	339	706-725	0.0015	0.01
5/18/89	M5-13	297	550-557	0.0042	0.02
5/18/89	M5-14	565	550	0.018	0.11
5/18/89	M5-15	620	550	0.018	0.12
5/19/89	M5-16	328	550-707	0.0078	0.04
5/19/89	M5-17	369	550	0.0075	0.04
5/19/89	M5-18	570	595-510	0.0084	0.05

of the analyses of charcoal tubes collected at this point were used to speciate the organic compounds in the exhaust stream. Table 8 shows the organic compounds found in the flue gas. The average detection limit for the 400-mg/200-mg charcoal tubes was 0.65 ppb; the average detection limit for the 100-mg/50-mg charcoal tubes was 17 ppb. NIOSH 1300 results revealed only one instance where concentrations at the FBCI exhaust were above the method detection limits. This occurred during Test-23 for the chemical toluene, which was detected at a concentration of 2.0 ppb.

3. Continuous Emissions Monitoring Results

Continuous Emissions Monitoring (CEM) of the FBCI unit was performed at the exhaust. EPA Method 25A was used to monitor TUHC at the FBCI exhaust. The flue gases, CO, CO_2, O_2, and NO_x were also continuously monitored. Results are summarized in Table 19.

Continuous monitoring of the flue gases, CO and NO_x, demonstrated concentrations that were consistently below general RCRA regulatory specifications for incinerators[15] NO_x values ranged from 7.0 to 20.0 ppmv, with an average of 11.6 ppmv. CO concentrations ranged from 16 to 110 ppmv, with an average value of 59 ppmv. The maximum of 110 ppmv CO occurred during Test-23 for which MEK was

TABLE 19. FBCI: CEM RESULTS SUMMARY.

Date	Run Number	Actual Flow Rate (dscfm)	Actual Temperature (°F)	Emissions				
				CO (ppmv)	CO_2 (%)	O_2 (%)	NO_x (ppmv)	TUHC (ppmv)
5/10/89	Test-2	466	698	43	2.2	20.2	10.7	2.1
5/10/89	Test-3	348	950	58	0.6	19.8	19.3	0.5
5/10/89	Test-4	446	950	56	0.9	20.1	10.7	0.5
5/11/89	Test-5	402	1000	45	0.3	19.0	--	0.5
5/11/89	Test-6	495	950	--	--	--	--	0.5
5/11/89	Test-7	494	700	16	1.5	20.5	--	0.5
5/12/89	Test-8	535	965-1027	21	0.7	18.5	--	0.5
5/12/89	Test-9	691	809-805	40	1.1	20.4	--	0.5
5/16/89	Test-13	524	1002	19	2.3	20.1	20.0	0.7
5/16/89	Test-14	524	1002	--	--	--	--	0.5
5/17/89	Test-16	584	700	75	1.8	20.1	12.3	0.5
5/17/89	Test-17	580	700	--	--	--	--	0.5
5/17/89	Test-18	661	775	99	2.0	19.4	11.3	3.1
5/18/89	Test-5-13	297	550-557	68	1.2	20.1	9.9	1.2
5/18/89	Test-19	339	706-725	37	1.7	19.4	11.8	0.5
5/18/89	Test-20	565	550	68	1.1	20.7	10.1	1.6
5/18/89	Test-21	620	550	90	1.3	20.7	9.0	0.7
5/19/89	Test-22	328	550-707	59	1.7	20.7	11.6	0.5
5/19/89	Test-23	369	550	110	1.5	20.7	8.7	5.8
5/19/89	Test-24	570	595-510	89	1.3	20.1	7.0	1.3

shot directly into the inlet stream. Monitoring of CO_2 and O_2 showed averages of 1.4 and 20.0 percent respectively.

4. Destruction and Removal Efficiencies (DREs)

Destruction and Removal Efficiencies (DRE) were calculated for the FBCI for a total of 21 tests. NIOSH 1300 data were used to find the percent composition of the organic constituents in the influent waste stream. Calculated DREs are summarized in Table 17. DREs for the FBCI were consistently greater than 99 percent. The only exceptions occurred during Test-21 and Test M5-13 for which the respective DREs were 97.7 percent and 98.7 percent.

5. Power Usage Results

The propane gas usage for the FBCI was monitored continuously with a dry gas meter. Readings were taken periodically during each test. The daily power usage for the CI unit is summarized in Table 12. Results of the fuel usage, by Test Condition, are shown in Table 20.

A maximum daily rate of power usage of 656,000 Btu/hr occurred on May 12, 1989. Two tests were run on this date with the flowrates of 691 dscfm and 535 dscfm. Minimum daily power usage of 298,000 Btu/hr occurred on

TABLE 20. FBCI: POWER/VOCS DESTROYED RATIOS.

Date	Run No.	Test Condition No.[a]	Inlet (lb VOC/hr)	Outlet (lb VOC/hr)	VOCs Destroyed (lb VOC/hr)	Fuel Usage Rate (Btu/hr)	Power/VOCs Destroyed Ratio (MMBtu/lb VOC Destroyed)
5/10/89	Test-2	2	0.13	0.0013	0.13	370,000	3.0
5/10/89	Test-3	1	0.11	0.00024	0.11	434,000	3.9
5/10/89	Test-4	1	0.26	0.00024	0.26	490,000	1.9
5/11/89	Test-5	1	0.10	0.00025	0.10	525,000	5.1
5/11/89	Test-7	2	0.89	0.00029	0.088	548,000	6.2
5/12/89	Test-9	3	0.055	0.00042	0.054	548,000	10
5/17/89	Test-18	3	0.28	0.0022	0.27	498,000	1.8

[a]Test Conditions:
1. Low flow rate/high temperature (<450 dscfm, >750°F).
2. Optimum flow rate/optimal temperature (450 to 550 dscfm, 650 to 750°F).
3. High flow rate/high temperature (>550 dscfm, >750°F).

May 19, 1989. Three tests were run on this date. Their respective flowrates were 328 dscfm, 369 dscfm, and 570 dscfm.

For individual tests, the maximum power usage rates occurred during Test-7 and Test-9 and were each greater than 0.54 MM Btu/hr. Operating conditions were 494 dscfm and 700°F for Test-7, and 691 dscfm and 807°F for Test-9. Minimum power usage occurred during Test-2, for which operating conditions were 466 dscfm and 698°F. Under these conditions power was used at a rate of 0.37 MMBtu/hr.

6. Discussion

M5 results show that there is a clear dependence between flowrate and particulate loading. Figure 7 shows that flowrates above 500 dscfm do result in greater particulate emissions. Six tests were performed in which flowrate conditions were greater than 500 dscfm. These tests resulted in an average particulate loading of 0.14 lbs/hr. In eight tests for which the flowrate was less than 500 dscfm, the average emission rate was 0.04 lbs/hr. Operating at high flowrates, especially above those established by the manufacturer of an FBCI, can result in the entraining of catalyst by the flue gas. Visual inspection of the M5 filters collected at these

conditions confirm this. These filters had a thick, grey powder on them. The powder is suspected to be catalyst. Analytical testing of the filters was not performed to confirm this.

NIOSH 1300 test results were combined with the CEM hydrocarbon data to determine the mass emission rate of VOCs for the FBCI. The main purpose for collecting data by NIOSH sampling methods was to speciate the organics present in the gas streams. This information was then used to calculate the pounds of VOCs emitted. In general, NIOSH test results for the FBCI exhaust were consistently below method detection limits. The FBCI unit showed greater than 99 percent DRE for 19 of the 21 tests performed. One of the best DREs occurred during Test-23, where the maximum inlet concentration of VOCs was introduced. During this test, MEK was sprayed directly into the inlet stream for 15 minutes. Hydrocarbon levels were recorded as high as 4000 ppmv during the test period, resulting in an overall average of 752 ppmv. These high inlet concentrations were accompanied by detectable TUHC emissions at the FBCI exhaust. The resulting DRE was 99.6 percent. In cases where VOC levels at the inlet were very low, DRE calculations can be affected by detection limits at the

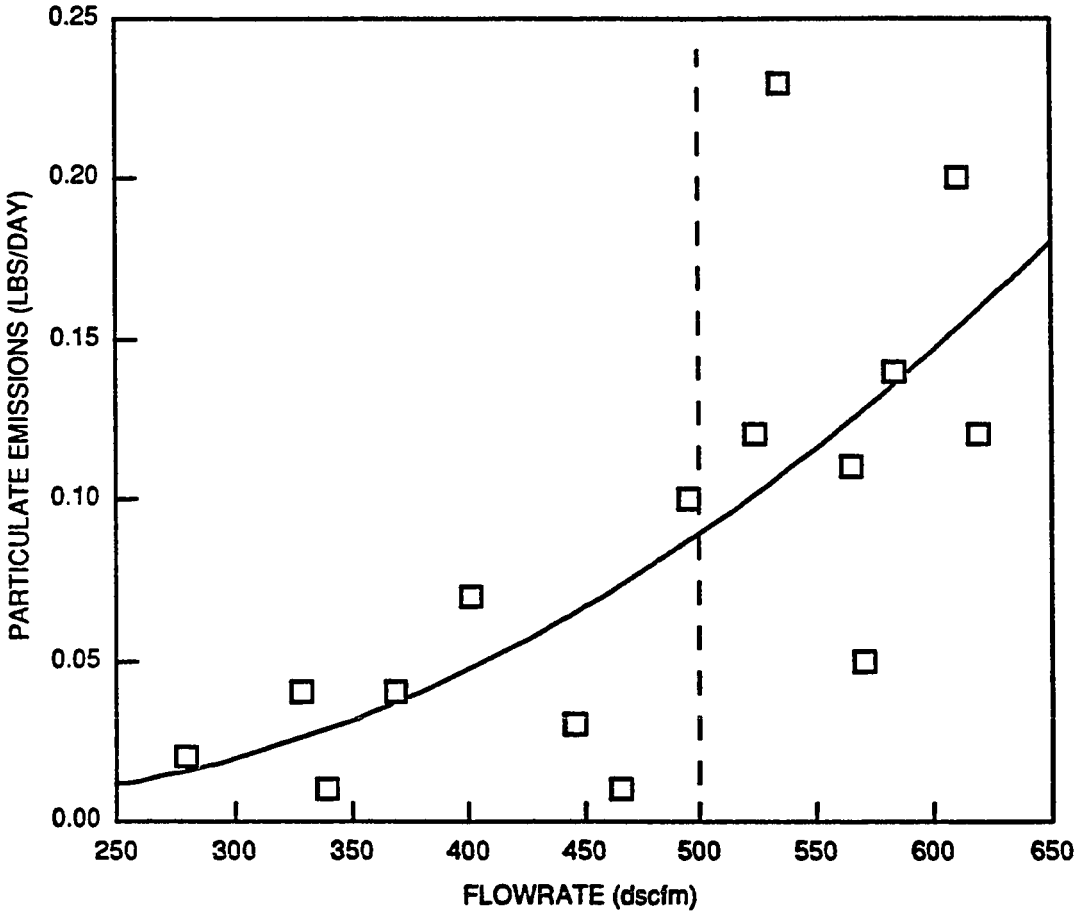


Figure 7. Flow Rate Versus Particulate Emissions.

FBCI exhaust. This is the case for Test-20 and Test M5-13, where DREs below 99 percent were calculated.

The dependence of power usage on temperature and flowrate for individual tests was evaluated. Review of Table 20 shows that no consistent correlations are apparent. When power usage is examined for the specific test conditions some trends are noticed (Tables 21 through 23). A minimum value of 459,000 Btu/hr occurred when the system was running under optimal conditions (Table 22). Higher consumptions were observed when conditions of greater temperature and higher flowrates were introduced. Condition 1 (low flow, high temperature) resulted in an average of 483,000 Btu/hr (Table 21). A maximum rate of 523,000 Btu/hr occurred for Test Condition 3 (high flow, high temperature) (Table 23). These data reveal that overall power usage is more directly affected by flowrate then temperature.

A similar correlation can be found in the results of daily power usage seen in Table 8. The maximum rate of usage occurring on May 12, 1989, corresponds to the highest average flowrate for tests performed on a single day. The minimum rate of usage occurred on May 19, 1989. This date was representative of the minimum average flowrate.

TABLE 21. TEST AVERAGES: FBCI TEST CONDITION 1[a].

Date/ Time	Run Number	Rate of Usage (Btu/hr)	CO (ppmv)	NO_x (%)	Particulate Emissions (lb/hr)	DRE (%)
5/10/89 1300-1340	Test-3	434,000	58	19.3	--	>99.8
5/10/89 1830-1930	Test-4	490,000	56	10.7	0.03	>99.9
5/11/89 1030-1130	Test-5	525,000	45	--	0.07	>99.8
Average:		483,000	53	15.0	0.05	>99.8

[a]Low flow rate/high temperature, <450 dscfm, >750°F.

TABLE 22. TEST AVERAGES: FBCI TEST CONDITION 2[a].

Date/ Time	Run Number	Rate of Usage (Btu/hr)	CO (ppmv)	NO_x (%)	Particulate Emissions (lb/hr)	DRE (%)
5/10/89 0930-1030	Test-2	370,000	43	10.7	0.01	>99.0
5/11/89 1655-1755	Test-7	548,000	16	--	0.10	>99.2
Average:		459,000	29.5	10.7	0.055	>99.1

[a]Optimum flow rate/optimum temperature, 450 to 550 dscfm, 650 to 750°F.

TABLE 23. TEST AVERAGES: FBCI TEST CONDITION 3[a].

Date/ Time	Run Number	Rate of Usage (Btu/hr)	CO (ppmv)	NO_x (%)	Particulate Emissions (lb/hr)	DRE (%)
5/12/89 1235-1315	Test-9	548,000	40	--	--	>99.2
5/17/89	Test-18	498,000	99	11.3	0.20	99.2
Average:		523,000	70	11.3	0.20	>99.2

[a]High flow rate/high temperature, 550 dscfm, >750°F.

Values for the PVDRs for the FBCI are listed in Table 20. When the PVDRs are viewed for each test condition, there is an apparent trend of an increasing ratio with increasing temperatures or flowrates. This is expected, but there are not enough data points to make a conclusion. Under optimum operating conditions (Test Condition 2) the FBCI had a PVDR of 4.58 MMBtu/lb VOC destroyed.

This FBCI achieved DREs of 99 percent or greater under a variety of operating conditions, including those that were beyond those established by the manufacturer. While operating at flowrates above manufacturer suggested ranges, the FBCI showed higher particulate loadings. Emissions of criteria pollutants were not significant, except that CO levels may peak above 100 ppmv during periods of high loadings. Power consumption by the FBCI was high, always being greater than 0.3 MMBtu/hr. Power consumption increased when the unit was operated at a higher flowrate or higher temperature, as was expected.

CHAPTER V

QUALITY ASSURANCE AND QUALITY CONTROL

In order to ensure that valid data were collected, the Quality Assurance and Quality Control (QA/QC) Plan[14] was followed. Tests that were subjected to QA/QC criteria established in the QA/QC Plan were NIOSH 1300, Method 25A, Method 2, and BAAQMD Method ST-7. EPA Method 5 tests were required to meet the QA/QC objectives established by the test method.

A. Goals and Objectives for QA/QC

Precision, accuracy, and completeness objectives for the tests carried out are shown in Table 24. QA/QC objectives for the BAAQMD Method ST-7 are the same as for Method 25A. Precision was determined for the charcoal tube results by analyzing duplicate samples and performing matrix spike duplicate analyses of spiked blank charcoal tubes. CEM precision was evaluated by the use of standard reference gases, not duplicate analyses. This is due to the variability of the sampling stream and operating conditions, which make obtaining a duplicate sample impossible. Precision for the Method 2 tests

TABLE 24. PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES.

Measurement Parameter	Measurement/ Analytical Method	Reference	Precision Relative Percent Difference	Accuracy (percent recovery)	Completeness
Volume flows in ducts	EPA Method 2 Pitot tube	40 CFR 60 Appendix A	±20	±40	90
Particulate concentrations in ducts	EPA Method 5 Isokinetic sampling	40 CFR 60	N/A[a]	N/A	90
Organic compound concentrations in air	NIOSH 1300 carbon absorption extraction GC/FID	DHHS (NIOSH)[b] 84-100	±35	70 to 120	90
Hydrocarbon emissions	EPA 25A	40 CRF 60 Appendix A	±20	±20	N/A
Hydrocarbon emissions	Organic vapor analyzer	Manufacturer's manual	±20	±20	N/A

[a]N/A -- Not applicable, continuous process.
[b]NIOSH Manual of Analytical Methods, Department of Health and Human Services.

(velocity measurements) was checked by taking duplicate samples.

Accuracy for the NIOSH 1300 tests was assessed as percent recovery of the matrix spikes of the blank charcoal tubes. This assessed extraction efficiency and analytical recovery. Continuous monitoring test accuracy was checked each day by comparing monitors to the expected value of a reference gas.

Completeness was measured as the percentage of valid data obtained divided by the total number of samples collected.

B. QA/QC Results

Relative Percent Difference (RPD), Accuracy (Percent Recovery), and Completeness were determined for each measurement parameter, when applicable. Particulate sampling QA/QC was evaluated by following calibration guidelines established by EPA Method 5.

1. Volume Flow in Ducts

Table 25 shows the precision for the volume flow measurements in the ducts. Standard deviations or RPDs were calculated for the EPA Method 2 flow measurements made at the CPACI Inlet (Site 7) and the FBCI Inlet (Site 8). RPDs were calculated for duplicate

TABLE 25. EPA METHOD 2: QA/QC RESULTS.

Date	Run Number	Site Number	RPD (%)	Standard Deviation
5/11/89	Test 5	7	0.69	
		8	5.0	
5/12/89	Test 8	7		19
		83	2.1	
	Test 9	7	11	
		8	3.3	
5/15/89	Test 10	7	13	
	Test 12	7		5.7
5/16/89	Test 13	7	0.00	
		8	0.00	
5/17/89	Test 16	7	0.15	
		8	3.4	
	Test 17	7	1.4	
		8	2.8	
	Test 18	7		19
		8		25
5/18/89	Test 19	7		5.7
		8		5.5
	Test 20	7	2.5	
		8	0.18	
	Test 21	7	2.6	
		8	4.5	
5/19/89	Test 22	7	3.3	
		8	1.8	
	Test 23	7	0.86	
		8	0.27	
	Test 24	8	9.5	

measurements, while standard deviations were calculated for triplicate measurements. The RPDs and standard deviations presented in Table 25 represent all replicate samples taken. The highest RPD found was 13 percent. The highest standard deviation found was 25, or 4.1 percent.

EPA Method 2 flow measurements were generally made with a standard pitot tube. Standard pitot tubes are the references by which accuracies for other flow measurement instruments are checked. Therefore, no special measurements for accuracy were made for the flowrate measurements. All measurements made using S-type pitot tubes did not need special reference checks. The pitot tubes used conform to EPA Method 2 specifications.

Completeness for the flowrate measurements was 100 percent. One hundred-thirty seven velocity traverses were performed and thirty-three replicate measurements were made. Replicate measurements were usually taken at Sites 7 and 8, since these sites were the points where regular monitoring was performed during test periods to obtain data about air flow into each treatment unit.

2. Particulate Concentration Measurements

Particulate concentration measurements by Method 5 are subject to the calibration procedures established in

EPA Method 5. RPDs and accuracy evaluations are not relevant since the complexity of the sampling method precludes simultaneous duplicate tests. Completeness for particulate concentration measurements was 100 percent.

3. Organic Compound Concentrations by NIOSH 1300

Table 26 shows the RPDs, standard deviations and percent recoveries obtained for the NIOSH 1300 test results. This table presents these values by charcoal tube size, front or back half of charcoal tube, spike level used, and chemical used for the spike. RPDs for the NIOSH 1300 tests ranged from 0.48 to 5.3 percent charcoal tube was 3.95 percent. This occurred for the large charcoal tubes spiked with low levels of methoxy acetone. The highest percent recovery was for methoxy acetone in the small tubes with a low level spike. The percent recovery have averaged 124 percent. The lowest recovery averaged 91.6 percent. Ninety-one samples were collected and four background samples were not submitted since they were collected at an inappropriate flowrate.

4. Hydrocarbon emissions by EPA Method 25A and BAAQMD ST-7.

Table 27 shows the RPDs and accuracies for the continuous measurements of hydrocarbons. The average standard deviations for the hydrocarbon monitors was 0.8,

TABLE 26. NIOSH: QA/QC RESULTS.

Compound	Relative Percent Difference		Percent Recovery	
	Front (%)	Back (%)	Front (%)	Back (%)
Large Tubes, Low Levels				
2-butanone (MEK)	2.4	0.48	96.9	93.3
Methoxyacetone	5.3	2.6	107	103
Toluene	3.1	2.1	92.4	102
Butyl acetate	2.8	1.1	97.7	94.3
2-ethoxyethyl acetate	2.9	1.1	105	104
Large Tubes, Medium Levels				
2-butanone (MEK)	1.2	2.5	93.7	90.4
Methoxyacetone	1.1	3.4	113	107
Toluene	2.2	2.2	96.1	95.9
Butyl acetate	1.2	1.8	96.1	92.7
2-ethoxyethyl acetate	1.1	1.6	104	100
Small Tubes, Low Levels				
2-butanone (MEK)	3.7	3.2	97.2	103
Methoxyacetone	3.2	3.9	126	122
Toluene	4.1	3.0	97.9	106
Butyl acetate	3.1	3.1	98.3	97.9
2-ethoxyethyl acetate	2.8	3.5	106	104

TABLE 27. QA/QC RESULTS FOR TUHC MEASUREMENTS

QA/QC	EPA Method 25A Measurements[a]	BAAQMD ST-7 Measurements[b]
Standard Deviation	0.8 (3%)	8.6 (1.3%)
Mean	25.1 ppm	679 ppm
Accuracy (%)	±3.6%	±3.3%

[a]Method 25A Reference Gas Value: 26 ppm.
[b]ST-7 Reference Gas Value: 657 ppm.

or 3 percent. The average accuracy for all hydrocarbon monitors was 3.6 percent. The standard deviation for the ST-7 method was 8.63, or 1.3 percent. The accuracy of the ST-7 method was 3.3 percent. The completeness of testing was 100 percent.

a. QA/QC Discussion

(1) Volume Flow in Ducts. The QA/QC objectives for volume flow measurements were met. The RPDs are all within 20 percent as established in the QA/QC plan. Accuracy should be within the objective of 40 percent since measurements were made with a standard pitot tube. In order to calculate DREs and VOC emission rates, flowrate measurements of the influent air were used. Variation in flow measurements were noticed during testing of the pilot-scale devices. Changes of as much as 50 dscfm were observed for the influent air to each device. This variation can cause the DREs to change by as much as 2 percent. Therefore, calculated DREs can be expected to vary by + or -2 percent. These variations in flowrates were found for only the first two days of testing. During the second day of testing, it was discovered that flowrates were being affected by wind gusts, as has been described in Chapter III. The problem

was corrected so that flowrate fluctuations were not significant.

(2) Particulate Concentration Measurements. Particulate concentration measurements were made according to EPA Method 5 specifications. All samples were collected isokinetically and instrument calibrations were acceptable.

The five samples collected which had isokinetics outside of the specified ±10 percent range were still used. Four of the five samples were from the CPACI incinerator exhaust. The impact of the deviations from isokinetics had little impact on the particulate concentrations evaluations since there were so few out of specification.

(3) Organic Compound Concentrations by NIOSH 1300. RPDs and percent recoveries for the NIOSH 1300 measurements met the objectives established in the QA/QC plan. QA/QC objectives of + or -35 percent for the RPDs and 70 to 120 percent for percent recovery were easily met.

(4) Hydrocarbon Emissions by EPA Method 25A and BAAQMD ST-7. Standard deviations and accuracies for hydrocarbon emissions measurements met the objectives established in the QA/QC plan. QA/QC objectives of +

or -20 percent for both standard deviations and accuracies were easily met.

(5) Organic vapor analyzer (OVA). The OVA was never used during the test period. Therefore, QA/QC objectives do not apply. The instrument developed a calibration problem before the test began, and Acurex deemed that the unit would not be acceptable for use. Instead, a third TUHC analyzer was used and placed on the CPACI carbon paper exhaust. Three tests were run on May 10, 1989, before a TUHC monitor could be installed.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

A. CARBON PAPER ADSORPTION/CATALYTIC INCINERATION

1. Conclusions

CPACI is a technology which is capable of maintaining VOC DREs of >97 percent. During most of the tests the DREs were >99 percent. These DREs were achieved while the paint spray booth was operating in a normal production mode. This suggests that CPACI technology can effectively handle batch or intermittent loadings of VOCs. Some breakthrough of the carbon paper adsorber was observed during periods of extreme VOC loading. When influent VOC concentrations were sustained and greater than 4,500 ppmv the carbon paper removal efficiency was affected.

Satisfactory DREs occurred when the CPACI was tested at many different operating conditions (temperature and flowrates), including those lying outside of the manufacturer specifications. This implies that the technology can continue to control VOC emissions when it is being improperly operated.

There did not appear to be a correlation between the selected operating temperatures and CPACI DREs. Normally, DREs for incinerators can be linked to operating temperatures. In this case, the range of temperatures where the unit was tested may not have been broad enough to establish the expected relationship between DRE and temperature.

There also did not appear to be a correlation between the selected operating flowrates and CPACI DREs. DREs did not show any correlation with either high or low flows through the system. Throughput of the contaminant through the system appeared to be more important, as discussed above.

Flowrates of desorption air did effect power consumption. Increases of desorption air through the system will require more power to preheat it and then to heat it further in the catalytic incinerator. Flowrates through the carbon paper adsorption rotor should not greatly effect power consumption. Increases in the flowrate here would only increase the power needed by the induced draft blower. Also, power consumption could not be directly linked to the CPACI operating temperature.

Power consumption under optimal operating conditions averaged 0.03 MM Btu/hr. The low power consumption is clearly the product of the CPACI design concept which

demands that only the low volume desorption air be incinerated.

The CPACI had very low levels of air pollution emissions. Particulate matter concentrations in the CPACI exhaust averaged 0.0029 gr/dscf for situations in which operating temperatures and flowrates were the manufacturer specified values. Particulate matter emission rates, under those same conditions, averaged 0.001 lb/hr. VOC emissions under normal operating conditions averaged 0.00086 lbs/hr for the pilot scale CPACI. CO and NO_x emissions were not significant and were nearly ambient in nature.

Evaluation of the technology for efficiency demonstrated that during operation at optimal conditions, the pilot scale CPACI consumed 0.29 MM Btu per pound VOCs destroyed.

Table 28 summarizes the results of the CPACI pilot scale tests. The results presented are averages for the Test Conditions specifically addressed in the work plan.

B. Fluidized Bed Catalytic Incinerator

1. Conclusions

FBCI is a technology capable of maintaining DREs greater than 99 percent. These DREs were acheived during the batch processes typical of the job shop nature of AFB

TABLE 28. CARBON PAPER ADSORPTION/CATALYTIC INCINERATOR CONDITION SUMMARY.

Test Condition	Temperature Range (°F)	Inlet Flow Rate Range (dscfm)	Average DRE (%)	Average Organic Emissions (VOC lb/hr)	Particulate Emission (lb/hr)	Power Usage (Btu/hr)	Power/VOC Destroyed Ratio (MMBtu/lb VOC destroyed)
1	>650	<450	>99.0	0.00040	0.0005	33,700	0.38
2	550-650	450-600	>99.0	0.00086	0.001	30,700	0.29
3	>650	>600	>99.5	0.0015	0.0006	39,800	0.48

paint spray booths. The minimum DRE found was 97 percent, but this occurred on one occasion. Satisfactory DREs were obtained when the FBCI was evaluated at many different operating conditions, including those lying outside of the manufacturer specifications. The implication is that the FBCI can provide adequate VOC destruction when it is being operated improperly.

DREs did not seem to be correlated with either FBCI operating temperature or flowrate. Temperature and DREs were expected to show a relationship while flowrate and DREs were not. Lack of a relationship between operating temperature and DRE is probably due to insufficient quantities of data to properly characterize the relationship.

There does appear to be a correlation between the VOC DRE and the VOC concentration in the air stream being incinerated. While this relationship was not specifically investigated, it was noticed that at times of extreme VOC loadings some organics may breakthrough. Toluene, a very stable compound was found in the exhaust from the FBCI during a test when solvent coatings were sprayed directly into the exhaust vents of the paint spray booths.

Power usage for the FBCI was similiar to that of other catalytic incinerators.[2] When operating under

optimal conditions the power usage rate was found to be .459 MM Btu/hr. Flowrate, as opposed to temperature, was found to have a greater affect on the power usage rate. Power usage was found to increase as flowrate increased. Such a relationship was expected. As the volume of air passing through the FBCI is increased, the amount of energy needed to incinerate it will also increase.

Evaluation of the FBCI air emissions demonstrated that there is the potential for particulate air emissions. Particulate mass emissions were found to be a function of flowrate. Higher flowrates through the FBCI have a tendecny to entrain the fluidized catalyst. Tests in which flowrates were greater than 500 dscfm resulted in average particulate mass emissions of 0.14 lbs/hour. An average emission rate of 0.04 lbs/hour was found when flowrates were less than 500 dscfm. The average particulate matter concentration under optimal operating conditions was 0.0093 grains/dscf.

Emissions of criteria pollutants from the FBCI were low. The average VOC emissions under optimal operating conditions was 0.0008 lb solvent/hr. CO and NO_x concentrations averaged 59 ppmv and 11.6 ppmv respectively. A maximum CO concentration of 110 ppmv occurred during a maximum VOC loading event.

Table 29 summarizes the results of the FBCI pilot-scale test. Results shown are averages for the test conditions specifically addressed in the work plan.

C. Recommendations

The pilot-scale evaluation of FBCI and CPACI technologies has led to a number of recommendations concerning the full-scale application of these units to control the VOC emissions from Air Force paint spray booths.

Operation of both technologies according to the manufacturers specifications is the surest way to to acheive satisfactory DREs and acceptable fuel usage rates. Both technologies can acheive DREs of >99 percent, but the FBCI uses more power in doing so. Also, the FBCI may have a particulate emission problem at the full-scale size. Evaluation of the particulate mass emission rate of a full scale FBCI should be done to determine if the daily atmospheric loading is acceptable.

CPACI technology does not have a particulate emission problem but it may have VOC breakthrough problems. More studies are needed to evaluate the system's ability to handle a plug flow which is highly concentrated.

TABLE 29. FLUIDIZED BED CATALYTIC INCINERATOR CONDITION SUMMARY.

Test Condition	Temperature Range (°F)	Inlet Flow Rate Range (dscfm)	Average DRE (%)	Average Organic Emissions (VOC lb/hr)	Particulate Emissions (lb/hr)	CO (ppmv)	NO_x (ppmv)	Power Usage (Btu/hr)	Power/VOC Destroyed Ratio (MMBtu/lb VOC destroyed)
1	>750	<450	>99.8	0.00024	0.05	53	15.0	483,000	3.61
2	650-750	450-550	>99.1	0.00080	0.055	30	10.7	459,000	4.58
3	>750	>550	>99.2	0.0013	0.20	70	11.3	523,000	5.97

Technical evaluation of both units has established that both units can control the VOC emissions from an Air Force paint spray booth. The problems identified are not difficult to surmount. Selection of one unit over another for installation at an Air Force base will be mainly based on economics.

Economic data, as presented by the manufacturers, indicates that the CPACI unit is more expensive. Procurement and installation cost for a CPACI unit capable of handling 50,000 dscfm is $1,425,000. This compares to a $1,062,500 cost for a FBCI unit of similiar size. This cost difference is striking especially when one considers that the CPACI is theoretically a smaller unit. CPACI technology should take the solvent in the 50,000 dscfm and concentrate it into the smaller desorption air stream, 5,000 dscfm or less. Therefore, a smaller unit is needed to incinerate this air and the capitol cost might feasibly be lower. This apparently is not the way the market currently functions.

However, since the CPACI unit does utilize a smaller burner than the FBCI unit, the utility costs are less on an annual basis. CPACI energy costs for the 50,000 dscfm are $60,250/yr, as compared to $91,700/yr for the FBCI. It should be noted though, that the FBCI costs do not reflect the potential savings which can be obtained from

incorporating heat exchangers. The FBCI pilot-scale unit did not have heat exchangers.

When considering the economics and the essentially equivalent technical capabilities, it is recommended that the FBCI technology be applied to Air Force paint spray booths. FBCI technology may be able to perform slightly better during times of VOC loadings. Differences in power cosumption may not be as significant when heat recovery systems are applied to the FBCI unit. Thus, long term economic differences may not be significant.

APPENDIX A

TECHNICAL APPROACH/DATA REDUCTION METHODS

A. DREs and Organic Emission Rates

The DREs for each pilot-scale unit were calculated by combining NIOSH 1300 data with CEM data. This blending of data allowed a VOC emission rate to be calculated as well. NIOSH 1300 and CEM results pertaining to the influent waste stream were also used.

1. Type of Data Used

The following information was used to calculate DREs and VOC mass emission rates:

- Chemical composition as detailed from NIOSH 1300 sampling data of the inlet waste stream
- Flowrates going into each unit
- Flowrates of flue gas from each unit
- Concentration of organic carbon in the inlet stream (BAAQMD Method ST-7 results)
- Concentration of TUHC in flue gas from each unit (EPA Method 25A results)

2. Assumptions

Calculating the DREs and the organic emission rates involved the following assumptions:

- The organic speciation and relative composition of the flue gas is the same as the influent gas
- All values that appear as zero ppmv of TUHC will be read as 0.5 ppmv, the lower detection limit
- Flowrate of the flue gas from the carbon paper adsorber is the same as the flowrate of the influent gas

3. Approach Used

- Use NIOSH test data to determine what organic compounds are present in the waste stream
- Determine the percent composition of the solvent-laden gas
- Determine the fraction of carbon in each organic compound present
- Calculate the pounds of organic carbon per hour going into the unit. Use equation from BAAQMD Method ST-7. The equation is:

Equation (A-1):

$$\text{lb } C_{org}/\text{hr} = 1.86\text{E-}6 \times Q_o \times C_{org}$$

Q_o = influent flowrate (dscfm)

C_{org} = ppmv of organic carbon measured by Method ST-7

- Determine the pounds of VOC per hour going into the unit. Use NIOSH speciation data combined with ST-7 data

Equation A(-2):

$$\text{lb VOC/hr} = \text{lb } C_{org}/\text{hr}/(f_1 \cdot f_{c1} + f_2 \cdot f_{c2} + \ldots + f_n \cdot f_{cn})$$

Where: f_1 = the fraction of the first organic chemical present in the influent stream

f_n = the fraction of nth organic chemical present in the influent stream

f_{cn} = fraction of C in the nth chemical present

- Calculate the pounds of organic carbon per hour in the exhaust gas. Use TUHC measurements that are supplied as ppmv as propane. Divide this by 3 to obtain the data as organic carbon in ppmv. Now apply Equation (A-1) using the adjusted TUHC data.
- Determine the pounds VOC per hour being emitted by using Equation (A-2)
- Determine the DRE of VOCs by using Equation (A-3)

Equation A-3:

DRE = [(Mass Flowrate In - Mass Flowrate Out)/ Mass Flowrate In] x 100

- KPR System overall DREs and VOC emission rates will incorporate the results from the incinerator and carbon paper adsorber

Example Calculations for Fluidized-Bed Catalytic Incinerator:

- Find organic compounds that are present in influent waste stream

Date: 5/16/89, NIOSH Test No. 13

	NIOSH Results	% of Total
MEK	0.9 µg/L	12
2-ethoxyethyl acetate	6.5 µg/L	88
Total	7.4 µg/L	100

- Determine fraction of carbon in each compound

	f_c
MEK	0.6663
2-ethoxyethyl acetate	0.5453

- Calculate lb C_{org}/hr going into the unit

Equation (A-4): (from BAAQMD ST-7)

$$\text{lb } C_{org}/\text{hr} = 1.86 \times 10^{-6} \, Q_o \cdot C_{org}$$

C_{org} = 39 ppmV (from St-7 data)

Q_o = 524 dscfm (from velocity traverses)

Inlet Mass Flowrate

$$\text{lb } C_{org}/\text{hr} = 0.038$$

- Determine pounds of VOC per hour going into unit

Equation (A-5):

$$\text{lb VOC/hr} = \text{lb } C_{org}/\text{hr} \div (f_1 \cdot f_{c1} + f_2 f_{c2} \cdots + f_n f_{cn})$$

$f_1 = f_{mek} = 0.12$ $f_2 = f_{2\text{-ethoxyethyl acetate}} = 0.88$

$f_{1c} = 0.6663$ $f_{2c} = 0.5453$

$C_{org} = 0.038$ lb/hr

$$\text{lb VOC/hr} = 0.038 \div ((0.12)(0.6663)+(0.88)(0.5453)) = 0.068$$

- Calculate lb C_{org}/hr for effluent gas
  - TUHC measurement: 0.7 ppmv as propane
  - Convert to ppmv as organic carbon. Divide TCHC measurement by 3.
    - 0.7/3 = 0.23 ppmv C_{org}

Equation (A-5) (Continued):

— Use Equation 1 again

— lb C_{org}/hr = 1.86×10^{-6} Q_o C_{org}

- Q_o = 684
- lb C_{org}/hr = 1.86×10^{-6} (684)(0.23) = 2.93×10^{-4}

- Determine lb VOC/hr being emitted. Use Equation (A-2). Assume percent chemical composition of exhaust gas is similar to influent waste stream.

lb VOC/hr = lb C_{org}/hr ÷ ($f_1 f_{c1} + f_2 f_{c2} + \ldots + f_n f_{cn}$)

So

lb VOC/hr = 2.93×10^{-4} ÷ ((0.12)(0.6663) + 0.88 (0.5453))

lb VOC/hr = 5.23×10^{-4}

- Determine DRE of VOCs

Equation (A-6):

$$DRE = \frac{\text{Mass flowrate in} - \text{Mass flowrate out}}{\text{Mass flowrate in}} \times 100\%$$

$$DRE = \frac{0.068 - 5.23 \times 10^{-4}}{0.068} \times 100 = 99.23\%$$

B. CEM Data Reduction Approach

Instantaneous readings of each parameter were recorded on strip charts over each hour sampling event. These readings were integrated to find average values for each event using the data reduction approach shown in Table A-1. Instrument drift and sampling system bias are

TABLE A-1. DATA REDUCTION APPROACH FOR CEM MEASUREMENTS.

Data Reduction Steps

- Count squares beneath curve
- Calculate average reading over time
- Find average zero sampling system calibration response
- Find average upscale gas sampling system calibration response
- Use Equation 6C-1 from Method 6C to calculate effluent gas concentration, dry basis, ppm

Equation 6C-1:

$$C_{gas} = (C-C_o) \times \frac{C_{ma}}{C_m - C_o}$$

C_{gas} = Effluent gas concentration, dry basis, ppm

C = Average gas concentration indicated by gas analysis, dry basis, ppm

C_o = Average of initial and final system calibration bias check responses for the zero gas, ppm

C_m = Average of inital and final system calibration bias check responses for the upscale calibraiton gas, ppm

C_{ma} = Actual concentration of the upscale calibration gas, ppm

incorporated as given by Equation 6C-1 of EPA Method 6C (40 CFR Part 60, Appendix A). Table A-1 presents the raw data used in Equation 6C-1 and the equation itself, and the final corrected average results for each sampling event.

C. NIOSH Data Reduction Approach

Results of the GC/MS analysis for each sample were divided by the volume of gas collected. This yielded a concentration (μg/L) of organic compound in the gas stream sampled.

D. M5 Data Reduction Approach

Particulate emissions were determined by the direct use of EPA Method 5. Raw data and calculations for each sampling run are given in Appendix B.

The measurements for the Method 5 analysis are:

- Pressure differential across the orifice meter
- Stack gas temperature
- Sampling temperature at the gas meter
- Stack gas pitot pressure differential (i.e., velocity pressure)
- Filter dry weight gain
- Probe wash dry weight
- Water condensate to fine stack gas moisture
- Stack gas O_2 and CO_2 to determine stack gas molecular weight

The step-by-step procedure of how these parameters are used to determine particle emission rate is shown in Table A-2, the isokinetic performance worksheet and particulate calculations. The amount of moisture in the stack is determined from the volume of liquid captured in the impingers and the volume of gas sampled, converted to standard conditions (68°F, 29.92 inches Hg). The molecular weight of the stack gas is calculated from the amount of carbon dioxide, oxygen, and nitrogen in the stack gas, which was determined from the CEM monitors. The stack gas velocity calculation also depends on the molecular weight. After weighing the particulate mass in the dried filter and in the probe wash, the particulate concentration and emission rate for each run is determined.

E. Power Consumption, Data Reduction

The first task was to categorize the raw data into one of the three previously identified test conditions. Since the operating conditions of the control unit fluctuated, only data which fell within the three operating conditions were used. In some cases, it was necessary to use engineering judgment because the operating set points and the actual readings fell within different categories.

Table A-2 ISOKINETIC PERFORMANCE WORKSHEET AND PARTICULATE CALCULATIONS

Plant_____ Performed by_____

Date_____

Sample Location_____

Test No./Type_____

Barometric Pressure (in. Hg)	P_b	
Meter volume (std), $17.64 \left(\frac{V_m}{\alpha}\right)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m + 460}\right)$ $17.64 \left(\frac{(\quad)}{(\quad)}\right)\left(\frac{(\quad) + \frac{(\quad)}{13.6}}{(\quad) + 460}\right)$	$V_{m\ std}$	
Volume of liquid collected (grams)	Vl_c	
Volume of liquid at standard condition (scf) $Vl_c \times 0.04707$	$V_{w\ std}$	
Stack gas proportion of water vapor $\frac{V_{w\ std}}{V_{w\ std} + V_{m\ std}}$, $\frac{(\quad)}{(\quad) + (\quad)}$	B_{wo}	
Molecular weight, stack gas dry (lb/lb-mole) (% CO_2 x 0.44) + (% O_2 x 0.32) + (% N_2 + % CO x 0.28) (____ x 0.44) + (__ x 0.32) + (__ + ____ x 0.28)	M_d	
Molecular weight, stack gas wet (lb/lb-mole) $Md(1-B_{wo}) + 18(B_{wo})$, (____)(1-____) + 18(____)	M_s	
Absolute stack pressure (in. Hg) $P_b + \frac{P_{stack}\ (\text{in. } H_2O)}{13.6}$, (____) + $\frac{(\quad)}{13.6}$	P_s	

TABLE A-2. ISOKINETIC PERFORMANCE WORKSHEET AND PARTICULATE CALCULATIONS (CONCLUDED)

Temperature stack gas, average (^{o}F)	T_s	
Stack velocity (fps) $85.49\ (C_p)\ (\sqrt{\Delta P_{s\ avg}})\ \sqrt{\frac{T_{s\ avg} + 460}{P_s\ M_s}}$ $85.49\ (\_\_\_)(\sqrt{\_\_\_})\ \sqrt{\frac{(\_\_\_) + 460}{(\_\_\_)(\_\_\_)}}$	$V_{s(avg)}$	
Total sample time (minutes)	θ	
Nozzle diameter, actual (inches)	N_d	
Percent isokinetic (%) $\frac{17.33\ (T_s + 460)(V_{w\ std} + V_{m\ std})}{\theta\ V_s\ P_s\ N_d^2}$ $\frac{17.33\ (\_\_\_ + 460)((\_\_\_) + (\_\_\_))}{(\_\_\_)(\_\_\_)(\_\_\_)(\_\_\_^2)}$	%I	
Area of stack (ft^2) $\pi = 3.1416$ $\pi r^2 \div 144$, $\pi(\_\_\_)^2 \div 144$	A_s	
Stack gas volume at standard conditions (dscfm) $60\ (1 - B_{wo})Vs_{avg}\ A_s \left(\frac{528}{T_{s\ avg} + 460}\right) \left(\frac{P_s}{29.92}\right)$ $60\ (1 - \_\_\_)(\_\_\_)(\_\_\_)\left(\frac{528}{\_\_\_ + 460}\right) \left(\frac{(\_\_\_)}{(29.92)}\right)$	Q_s	
Particulate matter concentration, dry (gr/dscf) $15.432\ \frac{M_p(grams)}{Vm_{std}}$, $15.432\ \frac{(\_\_\_)}{(\_\_\_)}$	$C_{s(std)}$	
Emission rate of particulate matter (lb/hr) $0.00857\ (Q_s)\ C_{s(std)}$, $0.00857\ (\_\_\_)(\_\_\_)$	E_p	

1. Carbon Paper Adsorption Catalytic Incinerator

The total power consumed and the rate of usage for each time period was calculated for pertinent test conditions. The power used in kW-hr for each time period was added up. The total power used was then divided by the interval time to obtain the rate of usage. This allows data from different time durations to be compared. In some cases a daily average had to be used because insufficient data were available for a specific time period.

2. Fluidized-Bed Catalytic Incinerator

The amount of propane used for each time period was obtained by the difference in the gas meter readings (ft^3). This amount was divided by the time interval and converted to Btu/hr by using the Lower Heating Value of propane = 2283 Btu/ft^3 (obtained from Mark's Standard Handbook, pp. 4-54).

F. Power/VOCs Destroyed Ratio

The fuel-use data along with data on the amount of VOCs destroyed were used to calculate destruction efficiencies for each unit. The amount of VOCs destroyed was calculated by subtracting the outlet from the inlet data. This quantity was then divided into the fuel-use

rate to obtain the amount of energy used per lb of VOC destroyed (MMBtu/lb VOC).

Examining the data shows that the PVDR is strongly dependent upon the operating condition. Data for Condition 3 shows low DREs because of the high temperature and subsequent high fuel use. Condition 1 DREs tend to be more favorable because of the lower flowrate, which is ideal for destroying VOCs. With the exception of one test run for the FBCI unit, all data fell within a consistent range. This run was probably effected by the low VOC loading and high energy use for Condition 3.

It should be noted, however, that data for all operating conditions tend to be somewhat dispersed due to uneven VOC loading and lack of stabilization for desired operating conditions. The effect of the solvent loading on the incinerator also could effect the amount of energy needed for destruction because the VOCs add to the energy content of the mixture.

APPENDIX B

DRE

1. Carbon Paper Adsorption Catalytic Incinerator
2. Fluidized-Bed Catalytic Incinerator

DIRECTORY OF SITE REFERENCE NUMBERS

Site Number	Site
1	Common Inlet
4	FBCI Exhaust
5	CPACI Carbon Paper Exhaust
6	CPACI Incinerator Exhaust
7	CPACI Inlet
8	FBCI Inlet

TABLE B-1. VOC DREs AND EMISSION RATES, McCLELLAN AIR FORCE BASE, FLUIDIZED-BED CATALYTIC INCINERATOR.

Date	NIOSH Test Number	Inlet Flow Rate (dscfm)	Inlet (ppmv)	Inlet (lb C/hr)	Fraction Solvent Composition Based on NIOSH Data[a]										Inlet (lb VOC/hr)	Outlet Flow Rate (dscfm)	Outlet (ppmv)	Outlet (lb C/hr)	Outlet (lb VOC/hr)	Unit DRE
					MEK	EAc	MeAc	MIBK	Tolu	BAc	Ebnz	Xyl	EtAc	MeEt						
5/10/89	2	466	103	0.089	0.62	0	0	0.14	0.05	0.07	0.01	0.08	0.01	0	0.127	720	0.7	0.00094	0.0013	98.9
5/10/89	3	348	123	0.080	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	0.113	543	0.17	0.00017	0.00024	>99.8
5/10/89	4	446	219	0.182	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	0.258	543	0.17	0.00017	0.00024	>99.9
5/11/89	5	402	98	0.073	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	0.104	553	0.17	0.00017	0.00025	>99.8
5/11/89	6	495	84	0.077	0.16	0	0	0	0.83	0	0	0	0	0	0.089	679	0.17	0.00021	0.00025	>99.7
5/11/89	7	494	28	0.026	0.50	0	0	0.10	0.34	0.04	0	0	0	0	0.034	679	0.17	0.00021	0.00029	>99.2
5/12/89	8	535	125	0.124	0.40	0	0	0.09	0.14	0.17	0.02	0.06	0.08	0	0.176	773	0.17	0.00024	0.00035	>99.8
5/12/89	9	691	30	0.039	0.40	0	0	0.09	0.14	0.17	0.02	0.06	0.08	0	0.055	948	0.17	0.00030	0.00042	>99.2
5/16/89	13	524	39	0.038	0.12	0	0	0	0	0	0	0	0.87	0	0.069	684	0.23	0.00029	0.00053	99.2
5/16/89	14	524	32	0.031	0.22	0	0	0	0	0	0	0	0.77	0	0.054	684	0.17	0.00022	0.00038	>99.3
5/17/89	16	584	82	0.089	0.4	0	0	0.14	0.06	0.11	0.02	0.11	0.12	0	0.127	794	0.17	0.00025	0.00036	>99.7
5/17/89	17	580	155	0.167	0.40	0	0	0.11	0.06	0.10	0.02	0.10	0.18	0	0.242	794	0.17	0.00025	0.00036	>99.8
5/17/89	18	611	168	0.191	0.40	0	0	0.11	0.06	0.10	0.02	0.10	0.18	0	0.276	794	1.03	0.0015	0.0022	99.2
5/18/89	19	339	33	0.021	0.76	0	0	0	0.23	0	0	0	0	0	0.029	438	0.17	0.00014	0.00019	>99.3
5/18/89	M5-13	297	45	0.025	0.76	0	0	0	0.23	0	0	0	0	0	0.034	423	0.4	0.00031	0.00043	98.7
5/18/89	20	565	30	0.032	0.18	0	0	0.05	0.20	0.13	0	0.02	0.04	0.34	0.048	726	0.53	0.00072	0.0011	97.7
5/18/89	M5-14	565	110	0.116	0.18	0	0	0.05	0.20	0.13	0	0.02	0.04	0.34	0.176	726	0.53	0.00072	0.0011	99.4
5/18/89	21	620	106	0.122	0.01	0	0.2	0.02	0.01	0.00	0.04	0.01	0.07	0.6	0.208	771	0.23	0.0033	0.00056	99.7
5/19/89	22	328	126	0.077	0.64	0	0	0.15	0.01	0.08	0.01	0.08	0	0	0.110	638	0.17	0.00020	0.00029	>99.7
5/19/89	23	369	752	0.516	0.71	0	0	0.02	0.11	0.03	0.00	0.01	0.10	0	0.752	639	1.93	0.0023	0.0033	99.6
5/19/89	24	570	216	0.229	0.33	0	0	0.08	0.14	0.20	0	0.13	0.01	0.08	0.322	723	0.43	0.00058	0.00081	99.7

[a]MEK = Methyl ethyl ketone
EAc = Ethyl acetate
MeAc = Methoxyacetone
MIBK = 4-methyl-2-pentanone
Tolu = Toluene
BAc = Butyl acetate
Ebnz = Ethyl benzene
Xyl = Xylenes
EtAc = 2-ethoxyethyl acetate
MeEt = 2-methoxyethoxy ethanol

TABLE B-2. VOC DREs AND EMISSION RATES, McCLELLAN AIR FORCE BASE, CARBON PAPER ADSORPTION/ CATALYTIC INCINERATOR.

Date	NIOSH Test Number	Inlet Flow Rate (dscfm)	Inlet (ppmv)	Inlet (lb C/hr)	Fraction Solvent Composition Based on NIOSH Data[a]										Inlet (lb VOC/hr)	Incinerator Exhaust Flow Rate (dscfm)	Incinerator Exhaust (ppmv)	Incinerator Exhaust (lb C/hr)	Incinerator Exhaust (lb VOC/hr)	Incinerator DRE
					MEK	EAc	MeAc	MIBK	Tolu	BAc	Ebnz	Xyl	EtAc	MeEt						
5/10/89	2	340	103	0.065	0.62	0	0	0.14	0.05	0.07	0.01	0.08	0.01	0	0.092	35	N/A	N/A	N/A	N/A
5/10/89	3	507	123	0.116	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	0.164	40	9.3	0.00069	0.000980	99.4
5/10/89	4	503	219	0.205	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	0.290	40	11.0	0.00082	0.001160	99.6
5/11/89	5	435	98	0.079	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	0.112	39	1.73	0.00013	0.000177	99.8
5/11/89	6	525	84	0.082	0.16	0	0	0	0.83	0	0	0	0	0	0.094	38	2.53	0.00018	0.000205	99.8
5/11/89	7	517	28	0.027	0.50	0	0	0.10	0.34	0.04	0	0	0	0	0.036	40	2.3	0.00017	0.000227	99.4
5/12/89	8	529	125	0.123	0.40	0	0	0.09	0.14	0.17	0.02	0.06	0.08	0	0.174	40	5.77	0.00043	0.000607	99.7
5/12/89	9	535	30	0.030	0.40	0	0	0.09	0.14	0.17	0.02	0.06	0.08	0	0.042	42	9.87	0.00077	0.001091	97.4
5/15/89	10	626	305	0.355	0.12	0	0	0	0	0	0	0	0.87	0	0.641	42	15.73	0.00123	0.002216	99.7
5/15/89	11	700	61	0.079	0.22	0	0	0	0	0	0	0	0.77	0	0.139	28	17.7	0.00092	0.001607	98.8
5/15/89	12	601	84	0.094	0.41	0	0	0.14	0.06	0.11	0.02	0.11	0.12	0	0.134	41	2.57	0.00020	0.000279	99.8
5/16/89	13	441	39	0.032	0.40	0	0	0.11	0.06	0.10	0.02	0.10	0.18	0	0.046	39	2.23	0.00016	0.000233	99.5
5/16/89	14	405	32	0.024	0.40	0	0	0.11	0.06	0.10	0.02	0.10	0.18	0	0.035	38	1.47	0.00010	0.000150	99.6
5/17/89	16	675	82	0.103	0.76	0	0	0	0.23	0	0	0	0	0	0.142	43	3.9	0.00031	0.000430	99.7
5/17/89	17	668	155	0.193	0.76	0	0	0	0.23	0	0	0	0	0	0.266	43	3.93	0.00031	0.000434	99.8
5/17/89	18	587	168	0.183	0.18	0	0	0.05	0.20	0.13	0	0.02	0.04	0.34	0.279	33	2.53	0.00016	0.000236	99.9
5/18/89	19	517	33	0.032	0.18	0	0	0.05	0.20	0.13	0	0.02	0.04	0.34	0.048	41	0.77	0.00006	0.000089	99.8
5/18/89	20	279	30	0.016	0.01	0	0.20	0.01	0	0.04	0.01	0.07	0.60	0	0.027	32	1.3	0.00008	0.000131	99.5
5/18/89	21	303	106	0.060	0.64	0	0	0.15	0.01	0.08	0.01	0.08	0	0	0.085	27	1.4	0.00007	0.000100	99.9
5/19/89	22	715	126	0.168	0.71	0	0	0.02	0.11	0.03	0	0.01	0.10	0	0.244	44	0.63	0.00005	0.000075	100.0
5/19/89	23	695	752	0.972	0.33	0	0	0.08	0.14	0.20	0	0.13	0.01	0.08	1.366	41	N/A	N/A	N/A	N/A

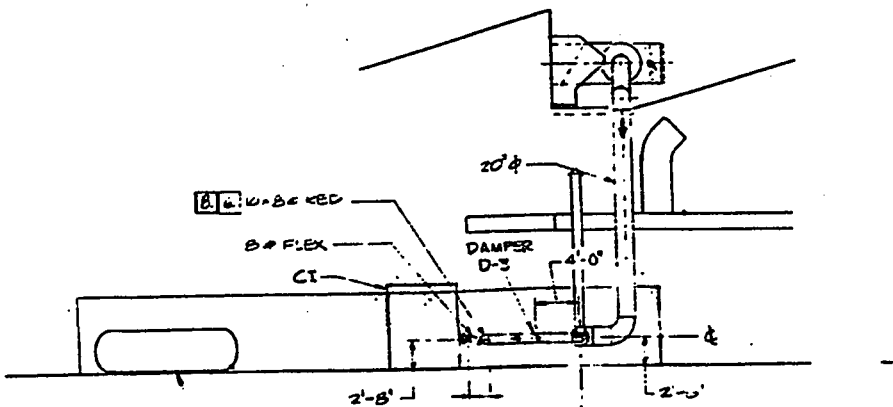
[a]MEK = Methyl ethyl ketone
EAc = Ethyl acetate
MeAc = Methoxyacetone
MIBK = 4-methyl-2-pentanone
Tolu = Toluene
BAc = Butyl acetate
Ebnz = Ethyl benzene
Xyl = Xylenes
EtAc = 2-ethoxyethyl acetate
MeEt = 2-methoxyethoxy ethanol
N/A = Not available

TABLE B-2. VOC DREs AND EMISSION RATES, McCLELLAN AIR FORCE BASE, CARBON PAPER ADSORPTION/ CATALYTIC INCINERATOR (CONCLUDED).

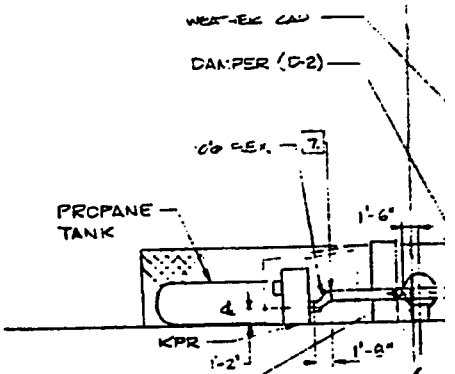
Date	NIOSH Test Number	Inlet Flow Rate (dscfm)	Inlet (ppmv)	Inlet (lb C/hr)	Fraction Solvent Composition Based on NIOSH Data[a]										Carbon Paper Exhaust Flow Rate (dscfm)	Carbon Paper Exhaust (ppmv)	Carbon Paper Exhaust (lb C/hr)	Carbon Paper Exhaust (lb VOC/hr)	Adsorp. Effic.	CPACI Total DRE
					MEK	EAc	MeAc	MIBK	Tolu	BAc	Ebnz	Xyl	EtAc	MeEt						
5/10/89	2	340	103	0.065	0.62	0	0	0.14	0.05	0.07	0.01	0.08	0.01	0	304	N/A	N/A	N/A	N/A	N/A
5/10/89	3	507	123	0.116	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	507	N/A	N/A	N/A	N/A	99.4
5/10/89	4	503	219	0.205	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	503	N/A	N/A	N/A	N/A	99.6
5/11/89	5	435	98	0.079	0.62	0	0	0.13	0.05	0.07	0.01	0.08	0.01	0	435	0.2	0.000161	0.000229	99.8	99.6
5/11/89	6	525	84	0.082	0.16	0	0	0	0.83	0	0	0	0	0	525	0.17	0.000166	0.000190	>99.8	>99.6
5/11/89	7	517	28	0.027	0.50	0	0	0.10	0.34	0.04	0	0	0	0	517	0.17	0.000163	0.000217	>99.4	>98.8
5/12/89	8	529	125	0.123	0.40	0	0	0.09	0.14	0.17	0.02	0.06	0.08	0	529	0.17	0.000167	0.000236	>99.9	>99.5
5/12/89	9	535	30	0.030	0.40	0	0	0.09	0.14	0.17	0.02	0.06	0.08	0	535	0.17	0.000169	0.000239	>99.4	>96.9
5/15/89	10	626	305	0.355	0.12	0	0	0	0	0	0	0	0.87	0	626	2.53	0.002945	0.005313	99.2	98.8
5/15/89	11	700	61	0.079	0.22	0	0	0	0	0	0	0	0.77	0	700	0.17	0.000221	0.000386	>99.7	>98.6
5/15/89	12	601	84	0.094	0.41	0	0	0.14	0.06	0.11	0.02	0.11	0.12	0	601	0.17	0.000190	0.000271	>99.8	>99.6
																				>99.1
5/16/89	13	441	39	0.032	0.40	0	0	0.11	0.06	0.10	0.02	0.10	0.18	0	441	0.17	0.000139	0.000201	>99.6	98.1
5/16/89	14	405	32	0.024	0.40	0	0	0.11	0.06	0.10	0.02	0.10	0.18	0	405	0.47	0.000354	0.000511	98.5	>99.5
5/17/89	16	675	82	0.103	0.76	0	0	0	0.23	0	0	0	0	0	675	0.17	0.000213	0.000294	>99.8	>99.7
5/17/89	17	668	155	0.193	0.76	0	0	0	0.23	0	0	0	0	0	668	0.17	0.000211	0.000291	>99.9	>99.8
5/17/89	18	587	168	0.183	0.18	0	0	0.05	0.20	0.13	0	0.02	0.04	0.34	587	0.17	0.000185	0.000282	>99.9	>99.1
5/18/89	19	517	33	0.032	0.18	0	0	0.05	0.20	0.13	0	0.02	0.04	0.34	750	0.17	0.000237	0.000361	>99.3	>98.9
5/18/89	20	279	30	0.016	0.01	0	0.20	0.01	0	0.04	0.01	0.07	0.60	0	279	0.17	0.000088	0.000150	>99.4	>99.7
5/18/89	21	303	106	0.060	0.64	0	0	0.15	0.01	0.08	0.01	0.08	0	0	303	0.17	0.000095	0.000137	>99.8	>99.8
5/19/89	22	715	126	0.168	0.71	0	0	0.02	0.11	0.03	0	0.01	0.10	0	715	0.17	0.000226	0.000329	>99.9	N/A
5/19/89	23	695	752	0.972	0.33	0	0	0.08	0.14	0.20	0	0.13	0.01	0.08	695	N/A	N/A	N/A	N/A	N/A

[a]MEK = Methyl ethyl ketone
EAc = Ethyl acetate
MeAc = Methoxyacetone
MIBK = 4-methyl-2-pentanone
Tolu = Toluene
BAc = Butyl acetate
Ebnz = Ethyl benzene
Xyl = Xylenes
EtAc = 2-ethoxyethyl acetate
MeEt = 2-methoxyethoxy ethanol
N/A = Not available

APPENDIX C



KPR - CATALYTIC INCINERATOR WEST EL. (B)



KPR - CATALYTIC

LTR	DESCRIPTION	DATE	APPD
D	AS BUILT	6-5-89	
C	RELEASED FOR PURCHASE	3-7-89	
B	[illegible]		
A	[illegible]		

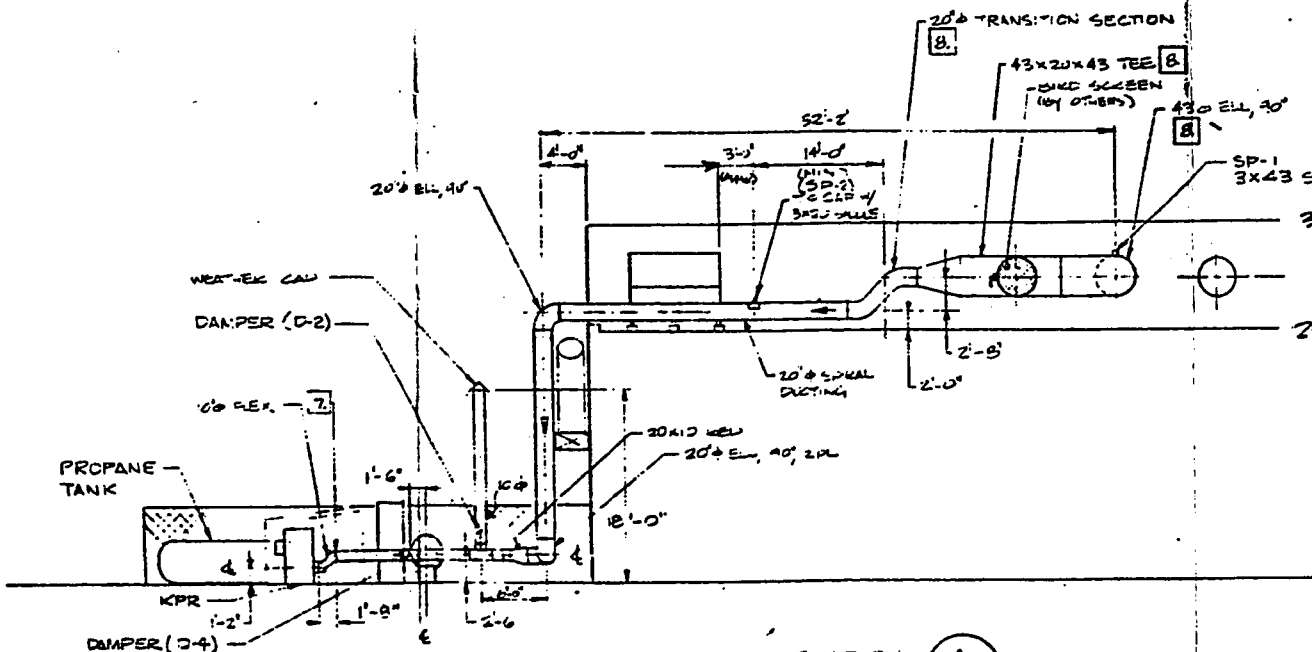
REVISIONS

LTR	DESCRIPTION	DATE	APPD

NUMBER

NOTES

1. ALL PIECES MUST MATE AS DENOTED DRAWING
2. ANY NON- INTERCHANGEABILITY OF PA MUST BE NOTED BY VENDOR AND UNIQ DUCTING PARTS MARKED ACCORDINGLY
3. LENGTH TRIMMING OF STRAIGHT DUCT WILL BE PERFORMED IN THE FIELD B ACUREX PERSONNEL. VENDOR TO NOTI SPECIAL TOOLS REQUIRED FOR THIS OPERAT
4. SADDLE INSTALLATION TO BE DONE IN THE BY ACUREX PERSONNEL
5. VENDOR TO DELIVER ALL PIECES OF EA PIECES DESTINED FOR INSTALATION ON TO BE PACKED TOGETHER.
6. 8Ø CAP REQUIRED ON REDUCER WHEN THIS UNI IN USE. FLEX WILL BE DISCONNECTED AT THIS
7. 10'Ø CAP REQUIRED WHEN THIS UNIT NOT IN U FLEX LINE WILL BE DISCONNECTED AT THIS TIM
8. SEE DWG NO. 8205P7005 FOR DETAILS.
9. DUCT SUPPORT NOT SHOWN FOR CL



B — KPR - CATALYTIC INCINERATOR NORTH ELEVATION — A

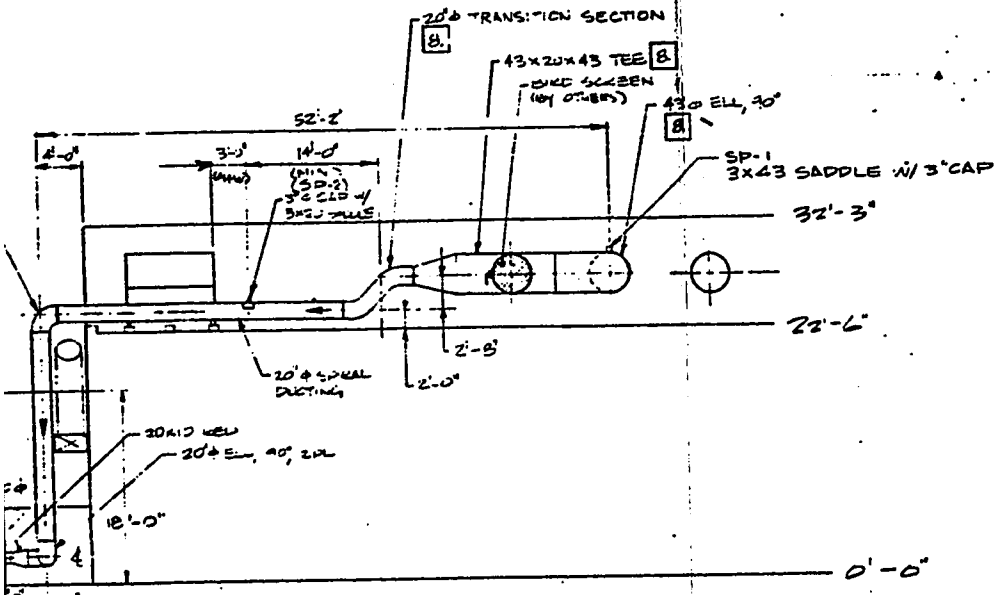
DATE	APPD	NUMBER	TITLE	NUMBER	TITLE

REFERENCE DRAWINGS

DWN
CHK
ENG
APPD
PROJECT NO 9205
SCALE 1/8" = 1'-0"

NOTES

1. ALL PIECES MUST MATE AS DENOTED ON DRAWING.
2. ANY NON-INTERCHANGEABILITY OF PARTS MUST BE NOTED BY VENDOR AND UNIQUE DUCTING PARTS MARKED ACCORDINGLY
3. LENGTH TRIMMING OF STRAIGHT DUCTING WILL BE PERFORMED IN THE FIELD BY ACUREX PERSONNEL. VENDOR TO NOTE ANY SPECIAL TOOLS REQUIRED FOR THIS OPERATION.
4. SADDLE INSTALLATION TO BE DONE IN THE FIELD BY ACUREX PERSONNEL
5. VENDOR TO DELIVER ALL PIECES ON PALLETS. PIECES DESTINED FOR INSTALLATION ON ROOF ARE TO BE PACKED TOGETHER.
6. BOOT CAP REQUIRED ON REDUCER WHEN THIS UNIT NOT IN USE. FLEX WILL BE DISCONNECTED AT THIS TIME.
7. 10'ϕ CAP REQUIRED WHEN THIS UNIT NOT IN USE. FLEX LINE WILL BE DISCONNECTED AT THIS TIME.
8. SEE DWG NO. 8205P7005 FOR DETAILS.
9. DUCT SUPPORT NOT SHOWN FOR CLARITY



NERATOR NORTH ELEVATION A

			DWN
			CHK
			ENG
			APPD
			PROJECT NO 8205
			SCALE 1/8" = 1'-0"
TLE	NUMBER	TITLE	

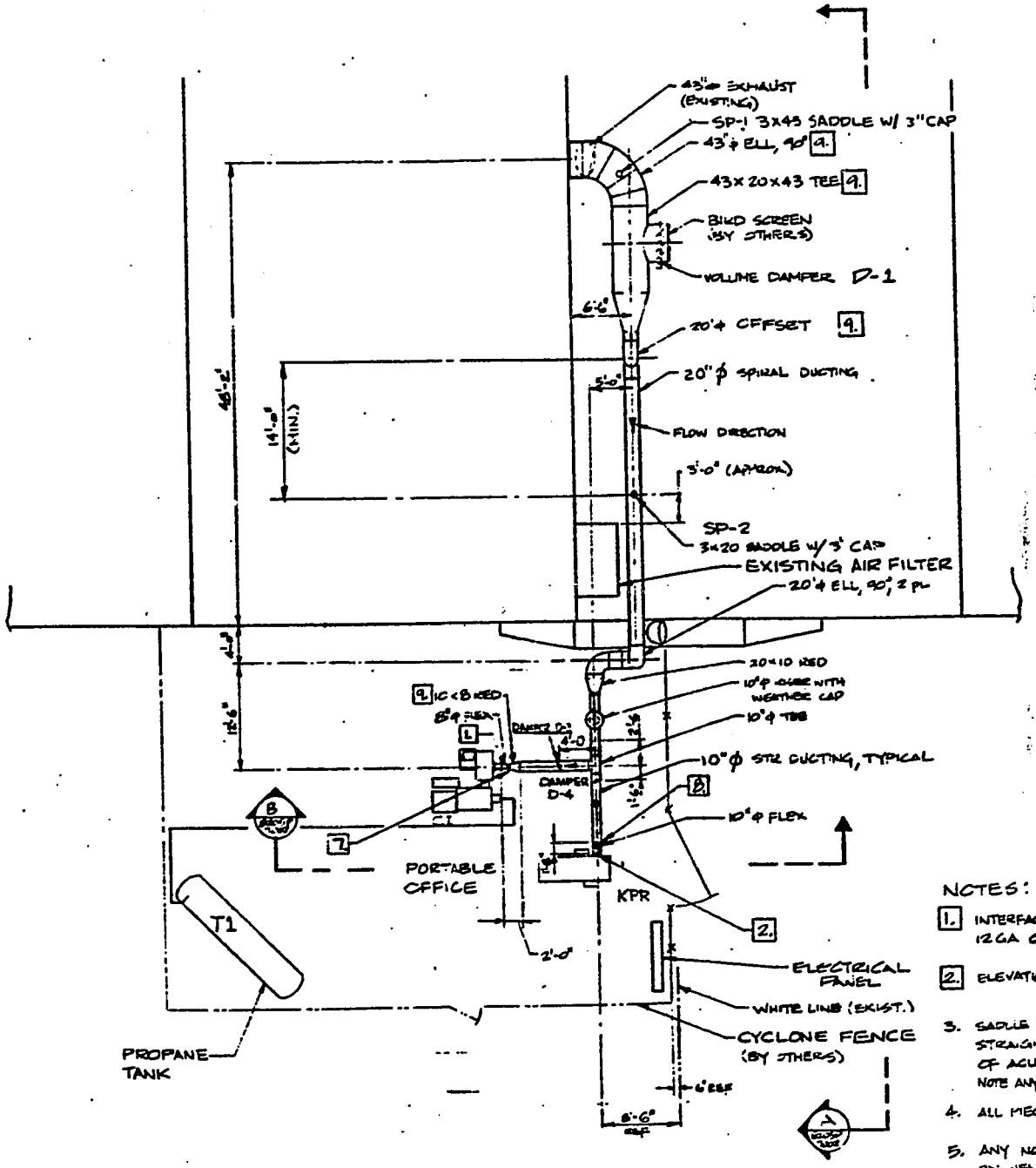
REFERENCE DRAWINGS

ACUREX Corporation — Environmental Systems Division

PROJECT

GENERAL ARRANGEMENT ELEVATION VIEWS

SIZE	DWG NO	SHEET	REV
D	8205P7002	1 OF 1	D



KPR & CATALYTIC INCINERATOR
(EVALUATION MAR-APRIL, 1989)

NOTES:

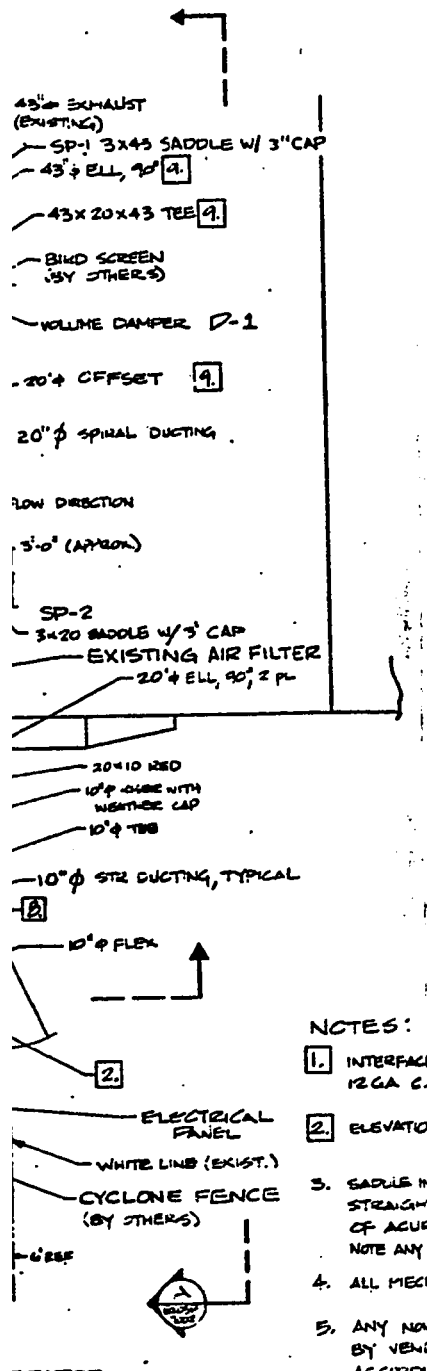
1. INTERFACE ... 12GA C.G.
2. ELEVATION ...
3. SADDLE INST... STRAIGHT OF ACURE... NOTE ANY SP...
4. ALL MECES...
5. ANY NON-... BY VENDO... ACCORDING...
6. VENDOR TO... DESTINED ... PACKED TO...
7. 8'ø CAP ...
8. 10'ø CAP ...

LTR	DESCRIPTION	DATE	APPD
D	AS BUILT	6-5-89	
C	RELEASED FOR INSTALLATION	3-7-89	
B	REVISED PER ECN		
A	RELEASED FOR BID		

REVISIONS

LTR	DESCRIPTION	DATE	APPD

NUMBER



NOTES:

1. INTERFACE HERE IS 8"ø ID, 2" LG OF 12GA G.G. ELEVATION OF INLET ℄: 2'-8".
2. ELEVATION OF INLET ℄: 1'-2".
3. SADDLE INSTALLATION AND LENGTH TRIMMING OF STRAIGHT DUCTS WILL BE THE RESPONSIBILITY OF ACUREX PERSONNEL IN THE FIELD. VENDOR TO NOTE ANY SPECIAL TOOLS REQUIRED FOR THIS OPERATION.
4. ALL PIECES MUST MATE AS DENOTED ON DRAWINGS.
5. ANY NON-INTERCHANGIBILITY OF PARTS MUST BE NOTED BY VENDOR AND UNIQUE DUCTING PARTS MARKED ACCORDINGLY.
6. VENDOR TO DELIVER ALL PIECES ON PALLETS. PIECES DESTINED FOR INSTALLATION OF ROOF ARE TO BE PACKED TOGETHER.
7. 8"ø CAP REQD ON REDUCER WHEN UNIT NOT IN USE.
8. 10"ø CAP REQD WHEN UNIT NOT IN USE.
9. SEE DWG NO. 8205P1005 FOR DETAILS.

DATE	APPD	NUMBER	TITLE

REFERENCE DRAWINGS

NUMBER	TITLE

DWN D. [illegible] 1-31-89
CHK A. [illegible] 1-31-89
ENG [illegible] 2-21-89
APPD

PROJECT NO.
SCALE 1/8" = 1'-0"

ACU Cor
PROJECT
GENI

[illegible]	08CE6
[illegible]	08SW1
[illegible]	08SW2

SIZE D
DWG 8

IS 8"ϕ ID., 2" LG OF
VATION OF INLET ℄ : 2'-8".

ET ℄: 1'-2".

ON AND LENGTH TRIMMING OF
WILL BE THE RESPONSIBILITY
SONNEL IN THE FELD. VENDOR TO
TOOLS REQUIRED FOR THIS OPERATION.

MATE AS DENOTED ON DRAWING.

HANGIBILITY OF PARTS MUST BE NOTED
D UNIQUE DUCTING PARTS MARKED

VER ALL PIECES ON PALLETS. PIECES
STALLATION OF ROOF AHE TO BE
ER.

REDUCER WHEN UNIT NOT IN USE.

EN UNIT NOT IN USE.

9. SEE DWG NO. 8205P1005 FOR DETAILS.

JUN 30 1988

TITLE	NUMBER	TITLE
REFERENCE DRAWINGS		

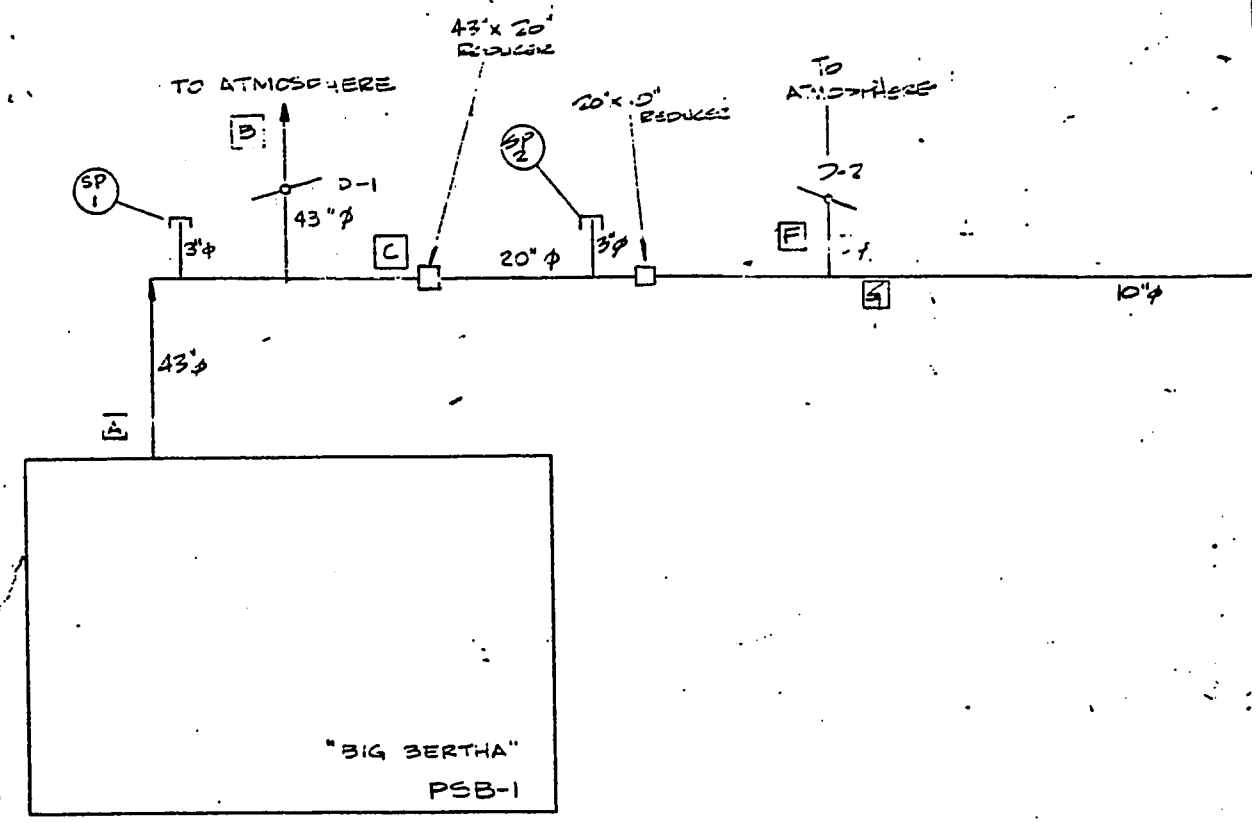
DWN	D. L.	1-31-89
CHK	A. Bag	1-31-89
ENG	[illegible]	2-2-89
APPD		
PROJECT NO.		
SCALE	1/8" = 1'-0"	

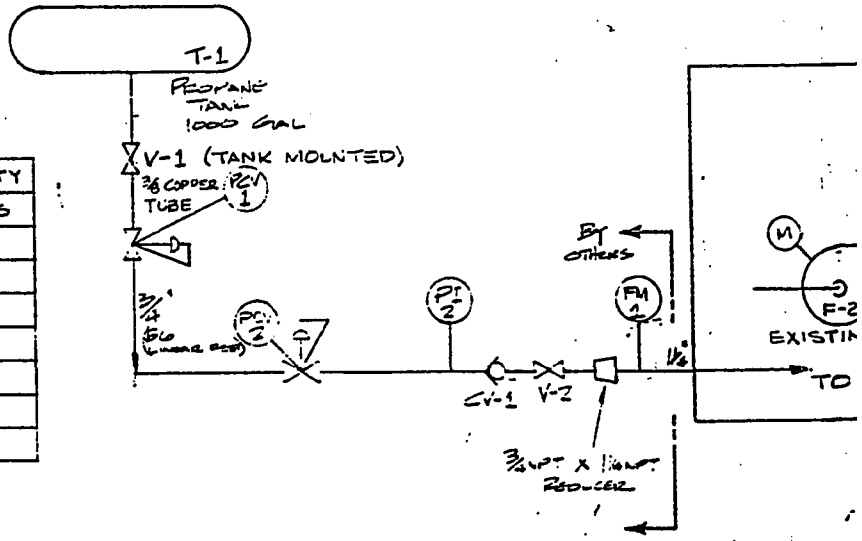
ACUREX Corporation — Environmental Systems Division

PROJECT

GENERAL ARRANGEMENT
PLAN VIEW

SIZE	DWG NO	SHEET	REV
D	8205 P 7001	1 of 1	D

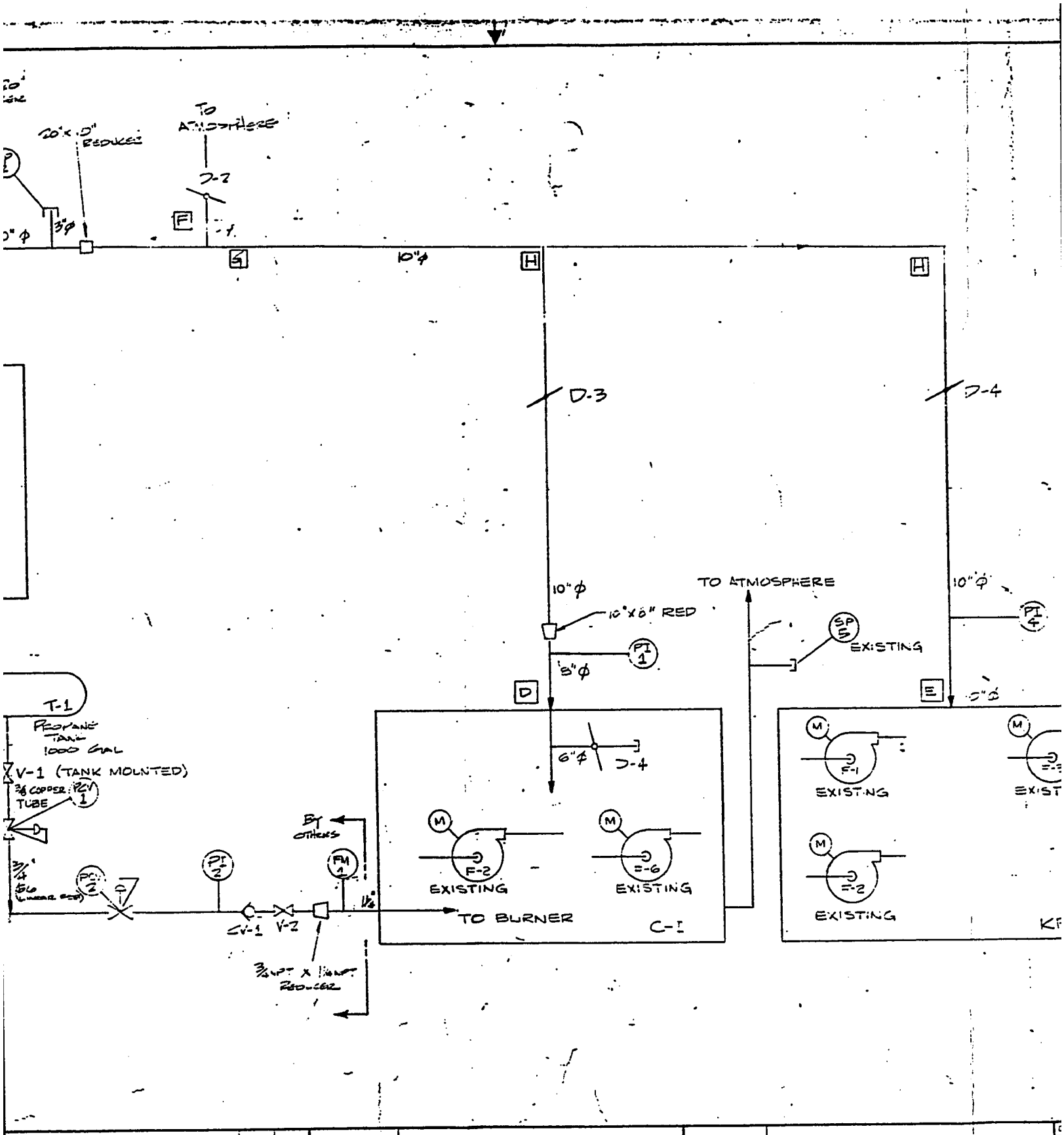




POINT	AIR FLOW RATE	VELOCITY
A	6,000 ACFM	50 FPS
B	2,000 ACFM	
C	4000 ACFM	
D	1000 ACFM	
E	700 ACFM	
F	2000 ACFM	
G	2000 ACFM	
H	1000 ACFM	

	DESCRIPTION	DATE	APPD	NO	DESCRIPTION	DATE	APPD	NUMBER
F	AS BUILT	02-89						
E	REVISED PROPANE LINE	4-87						
D	[illegible] REMOVE SP-2 & P-3; DELETE SP-4 & P-2	2-87						
[illegible]		8-86						
[illegible]		7-86						

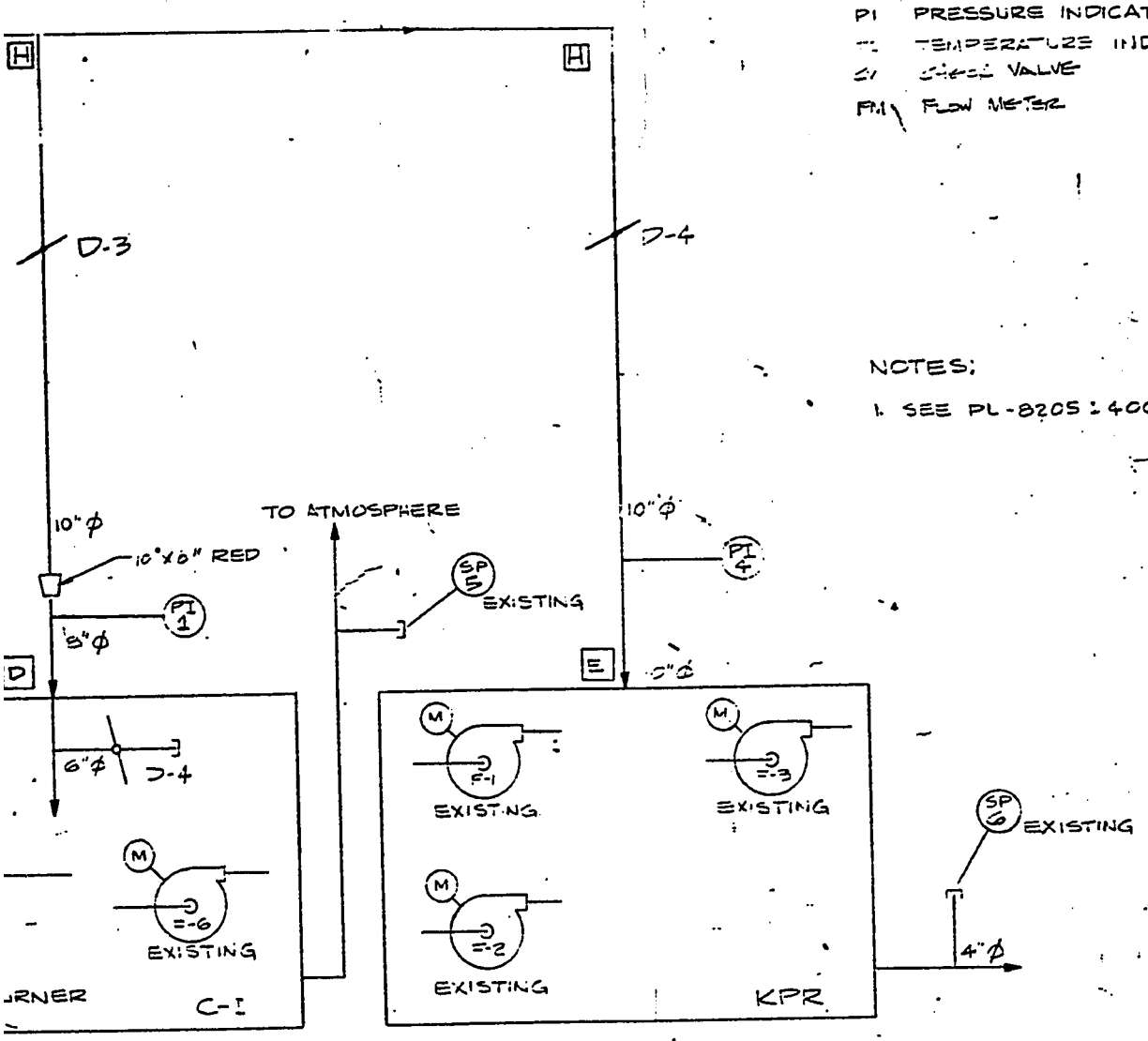
REVISIONS



DESCRIPTION	DATE	APPD	NUMBER	TITLE	NUMBER	TITLE
			REFERENCE DRAWINGS			

LEGEND

D MANUAL DAMPER
F FAN
PSB PAINT SPRAY BOOTH
SP SAMPLING PORT
PI PRESSURE INDICATOR
TI TEMPERATURE INDICATOR
CV CHECK VALVE
FM FLOW METER



NOTES:

1. SEE PL-8205:4004

JUN 30 1994

TITLE	NUMBER	TITLE
REFERENCE DRAWINGS		

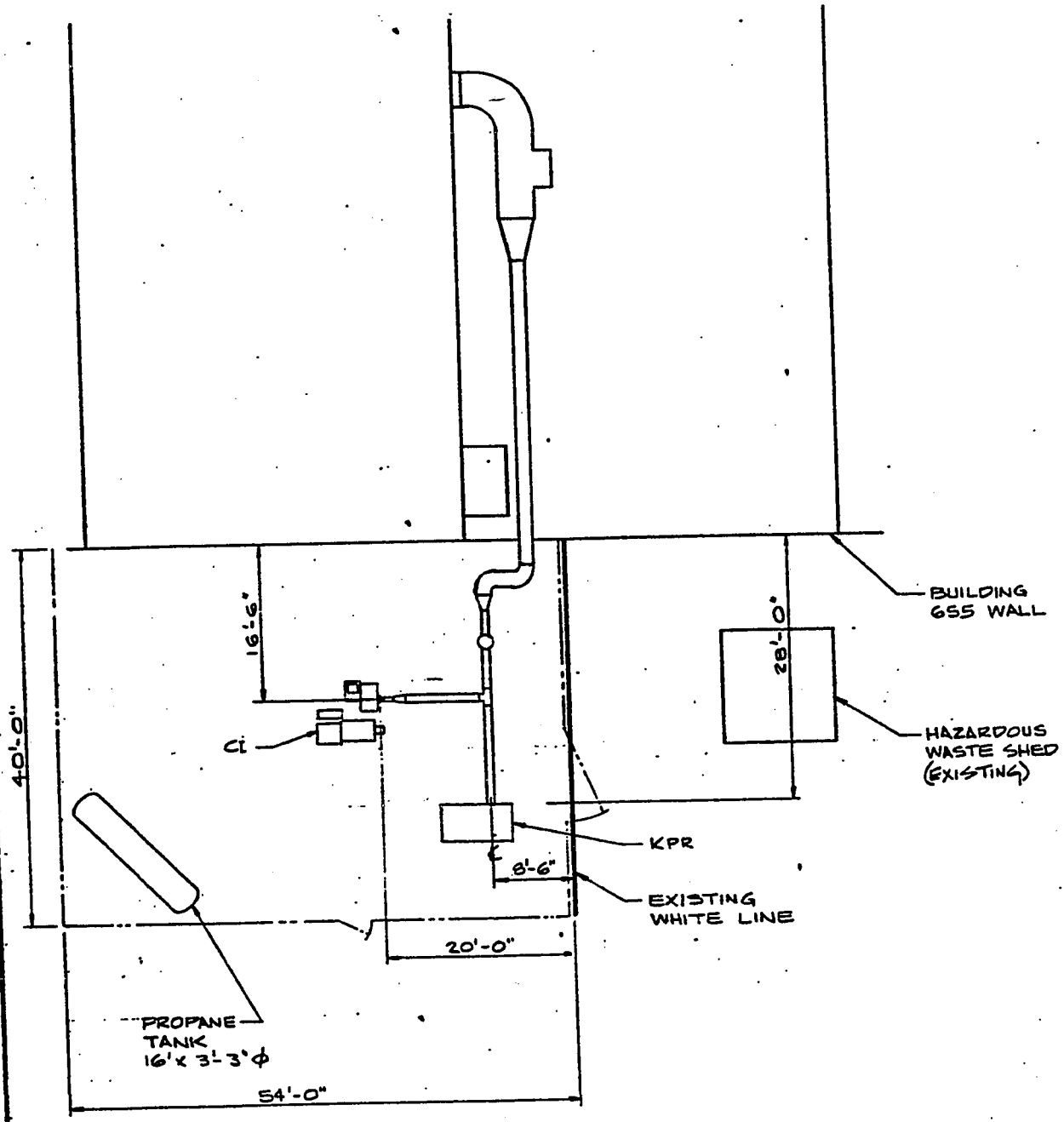
DWN
CHK J Boyd 1-31-94
ENG APPR
PROJECT NO 8205
SCALE —

ACUREX Corporation — Environmental Systems Division

PROJECT

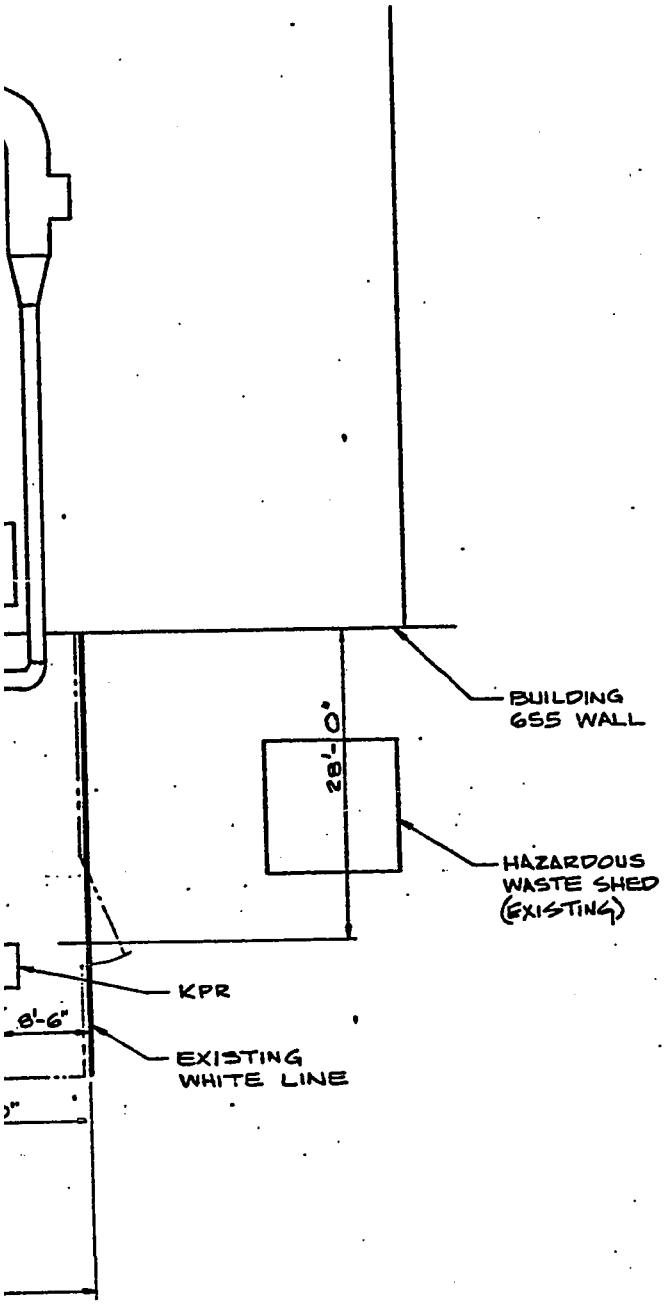
LPG/CATALYTIC INCINERATOR
PROCESS FLOW
DIAGRAM

SIZE D | DWG NO 8205-4004 | REV 1 | SHT 1 of 1



LTR	DESCRIPTION	DATE	APPD
C	AS BUILT	6-2-89	
B	RELEASED FOR INSTALLATION	2-7-89	
A	RELEASED FOR INSTALLATION	1/6/89	

REVISIONS

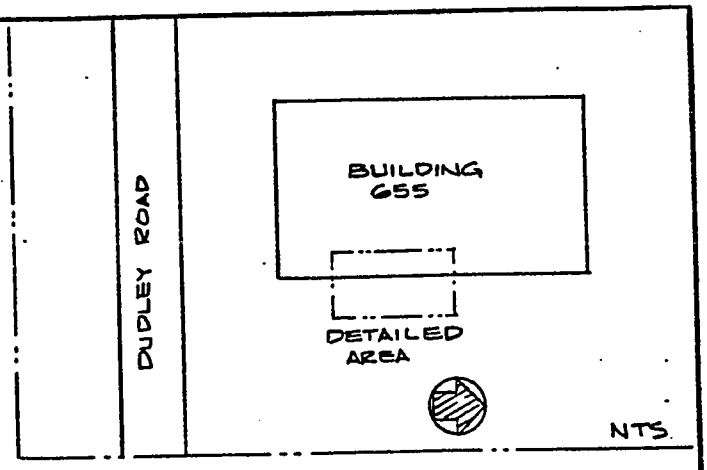


NOT
CI K
TIG-
AT T
CON

LTR	DESCRIPTION	DATE	APPD
C	AS BUILT	6-2-89	
B	RELEASED FOR INSTALLATION	3-7-89	
A	RELEASED FOR INSTALLATION	9/21/87	

SIONS

NUMBER	TITLE	NUMBER	TITLE
	REFERENCE DRAWINGS		



NOTES:

CI, KPR, EQUIPMENT TIE-DOWN POINTS AT THE CENTERLINE OF INTERFACE CONNECTIONS.

JUN 30 1989

TITLE	NUMBER	TITLE
REFERENCE DRAWINGS		

DWN DLG 2-14-89
CHK [illegible] 3/7/89
ENG [illegible] 3/7/89
APPD
PROJECT NO
SCALE 1/8" = 1'-0

ORIGINATING OFFICE	AGR NO
[illegible]	0883AB
[illegible]	0883W1
[illegible]	0883W1

ACUREX Corporation Environmental Systems Division

PROJECT

EQUIPMENT ARRANGEMENT PLAN VIEW

SIZE	DWG NO	SHEET	REV
D	8205P7004	1 of 1	C